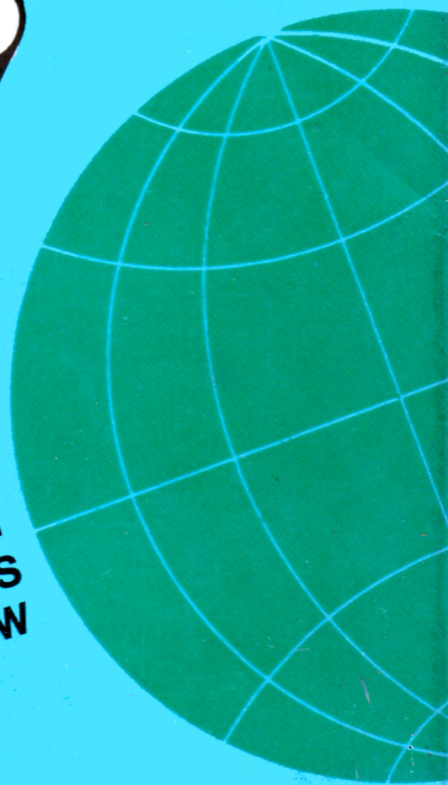


I. P. GERASIMOV

# GEOGRAPHY AND ECOLOGY



PROGRESS PUBLISHERS  
MOSCOW





I. P. GERASIMOV

# **GEOGRAPHY AND ECOLOGY**

A Collection of Articles  
1971–1981



PROGRESS PUBLISHERS  
MOSCOW

Translated from the Russian  
Devised by Vladimir Surikov

**Иннокентий Петрович Герасимов**

**ГЕОГРАФИЯ И ЭКОЛОГИЯ**

**Сборник статей 1971–1981**

*На английском языке*

Compilation and English translation © Progress Publishers 1983

*Printed in the Union of Soviet Socialist Republics*

Г  $\frac{20901-305}{014(01)-83}$  80-83

1905010000

# CONTENTS

Page

Preface. Problems in Ecology and Today's Geographic Science . .	5
<b>I. GEOGRAPHY'S CONTRIBUTION TO THE SOLUTION OF ECOLOGICAL PROBLEMS . . . . .</b>	<b>11</b>
The Scientific and Technological Revolution and the Soviet Geo- graphy . . . . .	13
Scientific Principles Concerning the Socialist Use of Natural Resources and the Objectives of Basic Research . . . . .	23
Methodological Problems in Extending the Ecological Appro- ach in Modern Science . . . . .	33
Constructive Geography as the Science of Goal-Oriented Trans- formations and Regulation of the Environment . . . . .	43
<b>II. STUDIES OF NATURAL ECOSYSTEMS (LANDSCAPES) AND OF THEIR ANTHROPOGENIC TRANSFORMATION . .</b>	<b>51</b>
The Material Cycle within Major Types of Natural Ecosystems of the USSR . . . . .	53
Theory of Natural Ecosystems (Geocobiotas) as a Synthesis of Landscape Science and Biogeocoenology in Soviet Geography and Biology . . . . .	64
Development of Scientific Fundamentals for Geosystem Monito- ring: Major Objective of Geography . . . . .	77
• A Facility for Experimental Field Studies of Natural and Anth- ropogenic Geosystems of the Central Part of the Russian Plain's Forest-Steppe Region (Analytical Description, Program, Initial Findings). . . . .	90
<b>III. GEOGRAPHIC ASPECTS OF MAJOR ECOLOGICAL PROBLEMS . . . . .</b>	<b>107</b>
Natural Hazards on the Territory of the USSR: Study, Control, and Warning . . . . .	109

The United Nations Conference on Desertification . . . . .	126
The Problem of Economic and Non-Economic Assessment of Man's Impact on the Environment . . . . .	137
Modern Constructive Geographic Problems of Large Cities . .	142
National Parks as a Form of Organizing Territories for Rest and Camping . . . . .	160

## PROBLEMS IN ECOLOGY AND TODAY'S GEOGRAPHIC SCIENCE

This is a collection of articles that have been written over the past ten years. All the articles deal with one basic theme, and the title of this preface essentially describes it. The author, a Soviet physical geographer, has for many years been concerned with the topics of this book. The question arises, does this subject merit such interest, and why?

The titles of the articles and the structure of the book itself provide the answers. The articles are grouped under three headings:

1. Geography's contribution to the solution of ecological problems.
2. Studies of natural ecosystems (landscapes) and of their anthropogenic transformation.
3. Geographic aspects of major ecological problems.

The term ecology, which stems from the Greek *oikos*, house, has a surprisingly different connotation than it did ten to fifteen years ago. Until very recently only biologists used the term and it was virtually unknown to the general public. Ecology did not enter the scientific vocabulary until the second half of the last century and was defined as the interrelationship of vegetation and animals with their environment. Biologists used the term extensively as Darwin's theory of evolution was further developed and taught. This "biological" interpretation is still in existence and some biologists consider "ecology" to be strictly in their domain.

Today, there can be no such dominion; ecology is

understood in a much wider context. The term may be applied to nature, man, society, and various forms of human activity. Terms such as "human ecology", "the social ecology", "ecological technology" and "ecological equilibrium in the environment" have sprung into existence. All this terminology essentially connotes the conservation of nature. It implies the need to preserve the existing environment, which is a result both of natural processes and of man's conservation efforts.

Primitive man ate wild fruits and berries, hunted and fished; he relied heavily on nature for his very existence. Even these basic activities damaged nature to some extent. At that time, man did not concern himself with conservation methods; however, nature was able to cope with whatever damage was inflicted, quickly restoring its resources.

As society developed, man's impact on nature grew in scope and strength. Until very recently we adhered to the following dictum: "We cannot expect favours from nature; we must take them." More often than not, no thought was given to the possible consequences of such "taking" from nature. But the consequences were significant and pervasive. Mankind has long trusted in nature's potential and restorative powers, though there was no reason to believe that these powers were inexhaustible. Only recently has man come to realize the necessity for conservation. Undoubtedly, this is a result of the revolution in science and technology which has dramatically increased man's ability to use natural resources. Nature had been increasingly damaged, restorative capabilities had progressively weakened, and human environment had deteriorated to the point of affecting the quality of life.

It was at this point that man realized the need to preserve and improve his environment; what is now called the ecological approach, or *Weltanschauung*, emerged. This approach is no longer concerned only with living elements of nature; it also applies to man and society, man's activities and his interrelationship with the environment.

One article in this collection is devoted to methodological problems in extending the ecological approach in modern science. Ecological awareness is evident both in the goals and the techniques of today's scientific research, and the science of geography is not to be excluded.

A new set of priorities in Soviet geographic studies has been brought about by the revolution in science and technol-

ogy. These priorities are clearly ecology-oriented and are discussed in the first article. This is a shortened version of the paper I presented at the 23rd International Geographical Congress held in Moscow in 1976. This new, ecological orientation of today's geographic research complies with the development of scientifically sound fundamentals for the use of nature in a socialist society and is discussed in another article. This article concerns the intensive anthropogenic "pressure" on nature, which is a world-wide phenomenon, as it occurs in Soviet socialist society. But the constructive power of developed socialism is able to overcome numerous objective difficulties. It provides great opportunities for effective planned protection of nature by society through the sensible use of natural resources.

The final article of the book's first section is titled, "Constructive Geography as the Science of Goal-Oriented Transformation and Regulation of the Environment". In my book *Soviet Constructive Geography* (1976) I discussed the constructive directions in geographic science today and tried to show that they could be found in all fields of geography. Still, the conservation of nature should be the top priority.

Two other sections of the book deal with the study of natural ecosystems and their anthropogenic transformation, and with the geographic aspects of major ecological problems. The articles in these sections are intended to serve as illustration and proof of the theories suggested in the first section.

The subject of natural ecosystems is more extensively discussed in the second section. This is understandable if one takes into account the author's field of research and the continuing interest of Soviet geography in natural landscapes. Especially important is the essay, "Theory of Natural Ecosystems (Geocobiotas) as a Synthesis of Landscape Science and Biogeocoenology in Soviet Geography and Biology". It outlines the history of Soviet landscape science and the close interrelationship of ideas between new branches in natural landscape science conducted by geographers, and the geobiological (biogeocoenotic) branch explored by biologists (geobotanists and zoogeographers). Foreign readers will, I believe, find much of interest in these scientific essays.

Two other articles in this section—one on the internal cycle of materials in natural ecosystems and the other on the

scientific foundation of geosystem monitoring--describe both the new, functional approach to natural ecosystems and the conventional scientific, practical approach by means of so-called geosystem or natural-economic monitoring. Although the concept of ecological monitoring (i.e., a system of observation of anthropogenic changes in the environment) is now very popular, its scientific basis and organisational principles need development in every respect. The corresponding article was written with this goal in mind.

The last article of the second section, which deals with an experimental testing ground for the study of natural and anthropogenic geosystems in the central region of the forest-steppe of the Russian Plain, is a fitting conclusion to this section. This article reports on many years of research conducted by a group of geographers at a representative station. Comprehensive comparative observations were carried out on abiotic factors (radiation and precipitations) and on the biological productivity (primary and secondary) of steppe virgin land and forest ecosystems and agricultural systems. In addition to the valuable results achieved, this testing ground may be of interest as a model for organizing similar stations. I am convinced that such organization, development and operation, would supplement conventional expeditionary field studies.

The final section, which addresses itself to geographic aspects of major ecological problems is more diversified, mainly due to the number and type of problems involved.

These problems are many and varied. This is shown to be the case in articles from the first section. However, as space is limited and the author has his own field of research, only a few of the problems are discussed. Three out of five articles are co-authored by colleagues who are well-informed about these topics and thus made it possible to diversify the subject matter of this section.

The section is introduced with a brief survey of natural hazards in the USSR. This survey was conducted for the Environmental Commission of the International Geographical Union and incorporated into its impressive report, *Natural Hazards. Local, National, Global* (1974). The destructive processes discussed in that article are worthy of more detailed discussion. These are all dynamic natural phenomena, very important ecologically; their devastating effect continues to increase even if the force remains un-

changed. This is due to the higher "sensitivity" of today's economy and population to natural hazards. Science, geography included, has failed so far to devise effective methods to counter such processes. The contribution of geography is still confined to studying the processes and developing methods for predicting the time and place of their occurrence. This too is valuable information.

The next article in the section is an essay on desert expansion and the struggle to cope with this devastating process which occurs worldwide. The essay summarises the findings of the UN Conference on Desertification held in Nairobi, Kenya, in 1978. The author was a member of the Soviet delegation and actively participated in the drafting of a meaningful proposal which was later included in the resolutions. The proposal states that integrated agricultural-and-industrial development should struggle against the anthropogenic expansion of deserts in arid regions. The article describes this project and its implementation in the USSR as part of an international programme.

The final three essays which were collaborated on, concentrate on urgent ecological problems which are of primary concern to Soviet constructive geography: to determine methods for the economic and non-economic assessment of man's impact on the environment (this project is included in a comprehensive scientific and technological CMEA programme); present-day constructive problems of large cities; and the development of national parks to be used for recreational activities of the urban population. The latter two problems are, of course, two sides of today's urbanization process, i.e., the concentration of population in the cities and the creation of an "antidote" to the polluted urban environment—"green" recreation zones.

All three problem areas clearly need extensive interdisciplinary research with biologists, economists, sociologists, engineers, and design agencies participating. The articles in this book are concerned only with the geographic aspects of these problems. We consider these aspects to be very important, if not essential to each problem area. Therefore, we again emphasize the leading role of geographic science in today's ecology—the role I proposed in the first section of this book.

To summarize, this preface is intended to give the reader an insight into the book. This will probably be sufficient if the reader is a geographer. The task is more difficult if the

reader is neither a geographer nor is familiar with geographic research today. There are still many people who fall into this category; they consider geographic science to be a descriptive, chiefly educational and informative field of knowledge without fundamental significance. It is hoped that this book will be successful in changing this traditional and outdated view and will provide for a better understanding of geographic ecological research.

Academician I. P. Gerasimov

**I.**  
**GEOGRAPHY'S CONTRIBUTION**  
**TO THE SOLUTION OF ECOLOGICAL**  
**PROBLEMS**

---



# THE SCIENTIFIC AND TECHNOLOGICAL REVOLUTION AND THE SOVIET GEOGRAPHY<sup>1</sup>

## THE SOCIAL FUNCTION OF GEOGRAPHY

It is common knowledge that for a long time geography was an integrated science studying nature, economy and population of the world. The notable geographical discoveries broadened the horizons of the world known to man, and provided human society with necessary scientific data on natural resources and conditions, and the economy and people of newly-populated territories.

Today, practical needs make a further detailed study of long-discovered areas more imperative. Providing scientific services for a diversified and intensive use of natural resources needed to satisfy society's varied needs has become a top priority matter for geography. At the same time the science of geography is increasingly important in substantiating socio-economic development of countries, locating their productive forces and improving the economic structure.

While performing its social functions, geography transforms from an integrated and universal science into a diversified system of sciences. Such specialized physico-geographical branches as geomorphology, climatology, hydrology, glaciology, oceanology and others have begun to develop especially rapidly in the Soviet Union. The development of such sciences as biogeography, that is, the geography of plants (geobotany) and the geography of animals (zoogeography) made large strides forward. Genetic soil science has also developed successfully. •

---

<sup>1</sup> *Earth and Universe*, 1977, No. 1 (in Russian).

The study of the rapidly developing economy and growing population has also promoted the appearance of some specialized fields of research. Socio-economic geography emerged as well as the geography of industry, agriculture, transport, etc. Historic geography has emerged independently.

All these branches of geography interacted with one another and also with many branches of related sciences, such as geophysics, geology, biology, economics, and history. Geography began, as it were, to lose its former integrity and to turn into a complex conglomerate of scientific branches.

But together with the process of differentiation, a fundamentally important potential for uniting the geographical knowledge and retaining geography's integrity as a fundamental science has not only survived but has intensified within geographic science. This potential is based on a need for a scientific cognition of various natural and historic properties of nature and socio-economic aspects of economic development and regional population, studied as integral units.

This complex and controversial situation in the science of geography has evoked prolonged discussions on the state of the science, the science's structure, methodology and prospects for further development. Only quite recently has the situation begun to change under the direct influence of new tasks related to the development of productive forces and also as a result of a greater complexity of geography's social function.

As is well known, the scientific and technological revolution increases society's impact on the environment. This impact on the environment constantly grows primarily as a result of a versatile and all-penetrating industrialization. The most pronounced forms of such an impact are:

- the withdrawal of increasingly large amounts of natural resources;
- the growing rates of production and consumption of power;
- profound physical and chemical transformations affecting a vast number of natural substances with the parallel process of discharge into the environment of various wastes, including noxious ones;
- changes in the agricultural and forest areas.

As a result of all these processes, and technological development which increasingly utilizes natural resources,

significant changes occur in most important properties of the biosphere. Climatic characteristics of the more intensively developed areas undergo changes which profoundly affect the natural biogeochemical cycles of materials, upsetting the complex world-wide balances of oxygen and carbon dioxide in the atmosphere. Considerable changes occur in the natural properties of soils which induce, in turn, changes in the quality of land resources. Successes achieved in soil irrigation, land cultivation and the use of chemicals are, however, accompanied by a loss of some very important protective natural properties. A list of irrevocable changes in the composition of flora and fauna increasingly grows.

The multifarious consequences of modern society's impact on the environment constitute the elements of one of the most pressing problems of today, namely, the problem of protection, conservation and transformation of the environment for the happy life and development of our and coming generations of people. It has become a universal truth that the protection, conservation and transformation of the environment are a task for inter-disciplinary research which requires considerable contributions on the part of scientists and specialists in many fields of science and technology. The solution of these most complex problems is possible only in conditions of peaceful coexistence, international cooperation and easing of international tension.

Which of the existing sciences can become a leader in a promising consideration of these complex problems of a rational utilization of the Earth's natural resources?

In our opinion, because of the entire course of its preceding development geography is prepared better than any other science for such research activities conducted on the basis of the joint participation of many branches of science. Geography has accumulated a huge volume of information on the natural conditions and resources of the entire world and on the degree and forms of their development and economic use. It is no less important that in handling these new formidable tasks geography can rely on the complex system of its branches. And finally, geography possesses an integrated approach to natural or socio-economic phenomena which is especially necessary for a successful scientific formulation of the problems posed.

On the other hand, one cannot overlook the tremendous importance of the new tasks mentioned above for geography itself as a fundamental science. Entrusted with important

social functions relating to the most acute and urgent problem of today, geography is acquiring new powerful impulses for its further development, overall consolidation of its contents and a further elaboration of both traditional and new research methods and approaches. On the basis of close relation with many related sciences, new fruitful contacts are presently emerging and should rapidly expand in time both within and outside of the system of geographic science itself. All of this, taken together, creates new possibilities for rapid progress for present-day geography and for the escalation to a higher stage of its development.

### **TASKS FACING GEOGRAPHY AS A FUNDAMENTAL SCIENCE**

We believe that today the following fields of research are the most urgent:

- a comprehensive study of the impact that society produces on the environment, a study of the principal forms, trends and intensity of environmental changes; a formulation of scientific forecasts of the most probable ecological consequences of such changes and also the preparation of scientifically valid methods of improving the consequences of society's impact on nature;

- further prospecting for and assessment of new volumes of natural resources, which are needed by the developing socialist society; and mapping out ways for their most rational utilization;

- the rational development, location and regional organization of production activities and population settlements;

- the mapping out of ways of goal-oriented transformations of the environment and the improvement of the population's standard of living, which can be accomplished, primarily, under conditions of a planned economy of a developed socialist society.

All these directions of geographic research are of great importance in order that the current Soviet geography fulfill its social function. The first direction of research occupies a special place and here we would like to point out several urgent problems requiring particular attention.

First of all, this is a development of the scientific bases of environmental monitoring and its rational organization. *By monitoring we mean a service providing a systematic*

observation of and control over the environment and its man-induced changes.

Sanitation and hygiene services as well as services keeping track of air and water purity form the initial stages of this monitoring. These services use quantitative indices of environmental quality widely in the form of maximum permissible concentrations of a number of substances, primarily, those that are toxic for man and living organisms.

This stage of *anthropogenic monitoring* (let us call it bioecological monitoring) is, nevertheless, insufficient for a comprehensive control of the environment. While constantly enlarging this stage, it is absolutely necessary to organize a monitoring system of a higher order (let us call it geoeological) designed to systematically follow changes in the environmental ecosystems and those in regional complexes, induced by man.

At the present time in the Soviet Union there are only fragmentary elements of such a monitoring system in the form of research stations, wild-life sanctuaries, and agricultural pilot stations. The task is, having increased these stations in number, to set up a sufficient and reliable network of posts for such geoeological monitoring which would ensure the desired reliability and effectiveness of the very important information received.

The highest stage of environmental monitoring is *biospherical monitoring*, designed to provide observation and control over global changes of the entire environment (biosphere). The objects of attention of such monitoring should include changes in the sun radiation, the atmosphere composition and the global water cycle as well as that of major chemical elements.

Global monitoring of the biosphere has not yet been organized, although measures have been taken for its creation. Geographers of various specializations should participate most actively in this important activity.

Another important component part of the direction being discussed is a development of scientific forecasts of the most probable geoeological consequences of anthropogenic effects on the environment. Such studies are presently called *scientific geographical forecasting*. These forecasts may and should be worked out for different geographic objects for various time periods.

One of the complex tasks of geographic forecasting is a determination of the character and intensity of responses of

the environment to an anthropogenic stress. In order to be able to assess the character and scale of such responses in a concrete situation, it is necessary to be aware of the essence of environmental processes. Therefore, the reliability and precision of geographic forecasting will depend primarily on the general level of theoretical geographic knowledge as well as on a knowledge of specific features of territories.

At the same time a development of scientific geographic forecasts should be based, of course, on the data provided by environmental monitoring. It seems probable that, like monitoring, geographic forecasts should also be applicable either to local or, what is even more important, to regional or global environmental changes. There is no doubt that the united front of such geographic forecasting should broaden as wide as possible.

The second of the current directions of geographic research mentioned above is a *further discovery of natural resources needed for society's development*. The scientific and technological revolution makes many kinds of mineral and other raw materials, that were previously considered as worthless, not only useful but sometimes even acutely needed; new kinds of power sources are placed into operation; and their interchangeability is increasing. All such technological shifts should be taken into account strictly in prospecting, economic evaluation and industrial application of natural resources.

Special emphasis should be placed on the development of *natural resources in territories with extreme climatic conditions* (Far North, deserts, high mountain ranges and the like). Modern production activities and populations armed with the newest of technologies are moving into these territories in growing numbers. The role of geographic science is especially large in their development since the interaction of nature and society assumes there specific forms. On the one hand, here environmental factors have a wide and stronger effect on man's economic activities creating rather stern conditions for his life. On the other hand, the nature of such extreme regions is especially vulnerable and irreversible changes occur especially rapidly in it as a result of anthropogenic stresses. Therefore, the role of geographic science for development of natural resources and productive forces in areas with extreme climatic conditions is especially crucial.

An important component part of geographic research of the environment and its resources are the geographers'

traditional studies of *natural disasters*. The task of geography in this respect is to minimize economic losses as much as possible and ensure the safety of the population. The newest geodetic and geophysical methods can and should be employed in tackling these tasks.

With the implementation of the first five-year economic plans in the Soviet Union the Soviet geographic science has participated in comprehensive research aimed at *increasing the effectiveness of territorial organization of social production*.

The need for studying a territory as an important category and object of modern constructive forecasting geography is evident. A number of important processes in the development of social production, attributable to the scientific and technological revolution, including above all its concentration and specialization of production, are responsible for radical changes in the socio-economic functions of territories and their rapid and profound transformations. All of this increases considerably the role of rational territorial division of labour in the development of productive forces.

The Soviet geographic science possesses a great creative potential for a fruitful scientific development of these new tasks. Soviet geographers are expected to take a most active part in their country's large-scale development of productive forces and, at the same time, to fulfil their present-day social function of preserving and improving the environment.

Geographical research into the *goal-oriented transformation of the environment* which is referred to in the USSR as constructive research is aimed at the elaboration of relevant measures to ensure the effective exploitation of natural resources, rational regional organization of social production and the creation of optimum living conditions. Such new forms and methods of interrelationships between society and nature in which the intensity of utilization, replacement and enrichment of natural resources will progressively increase while the environment will be purposefully and profoundly altered and improved, are becoming indispensable.

In other words, a further harmonic development of Soviet society (in the sphere of relations with nature) must have as its end result *planned progressive improvement of the general quality of the environment*. This involves man's active interference in the environmental processes.

In conditions of developed socialism, the optimally functioning environment should ensure a dynamic

development of productive forces with a maximum degree of reliability. It is necessary to study thoroughly the experience of mankind in the management of areas with a high concentration of population and production activities (large cities, industrial centres, and oases of intensive agriculture). It is very important to determine the criteria of environmental suitability for such areas for the people's community and its social progress. Such ecological criteria should supplement the economic ratings.

Another illustrative example of constructive geographic research carried out by Soviet scientists, is research in the theoretical basis of *recreation geography*. The development of recreations zones in the vicinity of large cities is an important alternative to the negative effects of urbanization.

The concept of close mutual links and interactions of all environmental components serves as a scientific basis for constructive geographic research.

A high and stable degree of goal-oriented transformation of the environment, ensuring a progressive increase of its productivity, will be achieved by means of constructing and designing new territorial systems for various functional applications (industrial, urban, recreational, agro-industrial, etc.). In such systems, natural environmental elements will be basically preserved or partly altered and supplemented with new technical elements which form an integral whole, together with environmental elements. It will hardly be appropriate to continue to refer to such structures as "complexes of nature (landscapes) transformed by man". It would be more correct to refer to them as "new structures of a natural-technical character" (or "geotechnical systems"). The construction of new *natural-technical structural complexes* by using modern methods of computation, modelling and planning should become a major task and the object of constructive research carried out by Soviet geographers.

We should clearly realize that these constructive tasks that geography is facing and that have been brought to life by the needs of the current scientific and technological revolution will first be solved on the basis of accumulated experience that the geographic science has at its disposal. Their solution should be based on an all-sided knowledge of the laws governing the organization and functioning of natural environmental systems, into whose introduction new technological elements should not upset the environmental processes but control them and to intensify those of them

that increase the overall quality of the environment and its resources.

The designing of new natural-technical structures should not be based on a contraposition of nature and technology, but rather on their rational cooperation and unity. At the same time it should be emphasized that the development of a constructive approach in geography requires a considerable extension of theoretical studies and research. An optimistic approach and a sober belief in the potential of science and man's mind, existing in the Soviet geography, come into a sharp conflict with the pessimistic tendencies of alarm-sounding non-Marxist environmentalists.

### CHANGES IN THE GEOGRAPHIC SCIENCE

An increase in the number of useable components of nature, a complexification of tasks related to their study and utilization, and the rational location of population and production activities make imperative the retention of the Soviet science within rather broad general boundaries and call for a need for its further differentiation. The many-sided contacts between the system of geographic sciences with many related sciences such as natural-historical, social, economic, technical and medical ones, are becoming more complex and multilateral.

At the same time the current geographic science acquires a particular goal-oriented character since it acquires a very important reference point—a responsibility to ensure a scientific elaboration of the protection and transformation of the environment in order to improve the effectiveness of territorial organization of the life of society, a rational utilization of natural resources, a further development of social production and the population's optimal living conditions. This major goal creates new stimuli for an overall consolidation of geographic disciplines, for a strengthening of the integrity of the entire system of our sciences. The new tasks facing geography today call for an accelerated development of its general theory which is needed for its new role of designing and forecasting.

It is also important to emphasize that the new tasks which geography is facing give rise to the need of a radical overhaul of its methods and approaches. However, some significant difficulties still remain which must be overcome. First of all, they consist of a need for a transition from qualitative and

•

descriptive geographic characteristics, to quantitative ones which are much more precise. In other words, what is needed is not just a further development and modernization of geography's traditional methods, but their radical reorganization. Thus, the traditional "component-by-component" approach to the subject being studied becomes considerably enriched when it is transformed into the modern *systems* approach. The potential of making topical maps is also great, whereas the research into theoretical cartography is acquiring much importance.

All these projects are feasible because of the wide possibilities which contemporary geography possesses as a result of the general progress in all the basic sciences and the newest technique of automatized means of monitoring experimental studies and the acquisition and processing of scientific data. Here we have in mind remote sensing made from satellites, topographical surveys and remote measurements, oceanographic (including underwater) expeditions, experimental studies using electronics and isotopic analysis, computerized information systems and systems of automated cartography.

The Soviet geographic science is successfully developing on a single methodological basis, that is Marxist-Leninist philosophy. This basis provides especially favourable conditions for the promotion and development of many directions of research which are brought to life as a result of a general pattern of social development in the USSR. Close links with the life of the entire people and the striving of the Soviet science to meet, most fully, the multifarious demands made on it by a developed socialist society and by the requirements of communist construction, determine the varied directions of scientific research. The shifts in the nature and rates of social production and its environmental impact in the period of the scientific and technological revolution attach special importance to the responsibility of geographers all over the world for the elaboration of the theoretical basis of an effective protection and improvement of the environment.

The noble task of Soviet geographers, in addition to an elaboration of these responsible scientific assignments and making constructive suggestions for their practical implementation, consists in a comprehensive merging of the achievements of the revolution in science and technology with the advantages offered by socialism.

## SCIENTIFIC PRINCIPLES CONCERNING THE SOCIALIST USE OF NATURAL RESOURCES AND THE OBJECTIVES OF BASIC RESEARCH

4

An Article of the Soviet Constitution reads: "In the interests of the present and future generations, the necessary steps are taken in the USSR to protect and make scientific, rational use of the land and its mineral and water resources, and the plant and animal kingdoms, to preserve the parity of air and water, ensure reproduction of national wealth, and improve the human environment."<sup>1</sup>

The chapter on the basic rights, liberties, and duties of Soviet citizens also contains an article which includes these words: "Citizens of the USSR are obliged to protect nature and conserve its riches."<sup>2</sup>

No capitalist country in the world has written anything of the kind into its constitution. This is not surprising, as it is only in a socialist country that the relationship among individual, society, and nature can and must comply with the scientific doctrine of Marxism-Leninism and be covered by the fundamental law of the state. The unrestricted use of natural resources in capitalist countries inevitably results in depletion. This was felt very early in the history of human society and became a hard fact of life as capitalist society developed. Lenin wrote that, "Capitalism creates large-scale

---

<sup>1</sup> *Constitution (Fundamental Law) of the Union of Soviet Socialist Republics*, Novosti Press Agency Publishing House, Moscow, 1977, pp. 27-28.

<sup>2</sup> *Ibid.*, p. 52.

production and competition which are attended by rapacious use of the productive forces of the soil.”<sup>1</sup>

The latest revolution in science and technology has considerably complicated the interrelationship between society and nature all over the world. One major result of this revolution has been the dramatic increase of anthropogenic influences on nature which was felt due to greater exploitation of natural resources and the rapid, multi-faceted industrialization and urbanization processes. Along with the many material benefits which have made human life and work easier, shortages of natural resources and the dramatic deterioration of the environment have appeared as a result of pollution of the air and water. In response to these unwelcome occurrences, a progressive movement has developed in capitalist countries for the protection of nature, more reasonable use of natural resources, and the struggle against pollution. Numerous books by leading scientists have been published concerning this problem; the titles of which—*Before Nature Dies*, *The Closing Circle* and *Only One Earth*—indicate its serious nature.

Pressured by the public opinion and economic factors the governments of capitalist countries do take some conservation measures. But their efforts are few and generally ineffective. This continuous exploitation of natural resources results in increasing shortages and in growing environmental pollution. The once glorious Rhine has become a gutter for Western Europe. In Tokyo the crimson evening sun sets into a dark cloud of suffocating smog. These occurrences which are so detrimental to nature and human life are inherent in a capitalist society where natural resources are considered to be private property, and where merciless competition results in the plunder of resources by profit-hungry monopolies.

The situation is quite different in the USSR. The Party and government have taken responsibility for the protection of nature, the rational use of its resources (which are considered to be a national asset) and the improvement of the environment. In keeping with the ultimate goal of social production under socialism, “to satisfy as much as possible the growing material and spiritual needs of the people”, the Constitution has incorporated articles on the protection and

---

<sup>1</sup> V. I. Lenin, “Marxist Views on the Agrarian Question in Europe and in Russia”, *Collected Works*, Vol. 6, Progress Publishers, Moscow, 1974, pp. 344-45.

rational use of natural resources. The Party and state see to it that these articles are strictly adhered to, adopt appropriate legislation, and support the wide desire to protect nature. In December 1978, the CPSU Central Committee and the Council of Ministers of the USSR enacted a resolution "On Additional Measures for Better Methods of Conservation and Improvements in the Use of Natural Resources" which reemphasized "that the conservation of nature and the rational use of natural resources in the context of rapid progress in industry, transportation and agriculture, and the increasing exploitation of natural resources, is one of the most important economic and social objectives of the Soviet state".

It is also stipulated in the resolution that industry, transportation, and agriculture should increase their efforts to conserve national resources. The State Committee for Hydrometeorology and Control of Natural Environment has been instructed to set up an effective service for verifying the observance of conservation measures and has the power to sanction the offenders. The committee may even halt or ban the operation of factories and mines that do not observe the guidelines for environmental protection. The fact that so many resolutions concerning conservation have been enacted by the Party and the government attests to the importance placed on natural resources and their conservation in the Soviet Union.

Joint efforts of the state and Party, scientific and engineering communities, and the Soviet public can solve even the most difficult problems faced in the rational use of natural resources and environmental protection. I shall cite only three examples of this cooperation:

Moscow, the capital of the USSR, which Soviet people are making into an exemplary communist city, has a multi-million population. Still it is considered to be one of the cleanest and most modern cities in the world. Nevertheless, in 1980 the State Committee on Science and Technology, the State Committee for Material and Technical Supply, and the Moscow City Council co-sponsored a decision providing for further comprehensive steps to reduce and abolish industrial wastes in the city. In accordance with this decision, factories and organizations in the city and the Moscow region took an accurate inventory of their wastes and devised methods for their recycling. Other

large industrial centres in the country will undoubtedly follow this example.

The public movement to protect Lake Baikal from industrial pollution by factories located in its basin is well known. The State Committee for Hydrometeorology in compliance with a government decision placed strict controls on the industries. Today the local factories have completed the design of a pilot waste-free water supply system for the Selenga Cellulose and Cardboard Works. When it is put into use, industrial waste from one of the largest factories in the region will no longer flow into the Selenga, the main tributary of Lake Baikal.

The engineers of Dzerzhinsk, a large industrial centre in the Ukraine, are well known for their efforts to protect the environment. In 1978 the city's thermal power station completed the construction of a unit which gasified highly sulphurous mazouth by pressure and purified the gas while extracting sulphur and vanadium from the smoke. In 1979 this new technology should be completely tested and preparations are underway for using the process in the entire station so as to reduce by five to ten times the amount of sulphurous compound emitted into the atmosphere.

Many such examples, characteristic of the socialist society, can be cited. They are widely reported in both technical and non-technical journals. I have chosen these three because, in my opinion, they combine technical innovation with public initiative.

Nevertheless, it would be erroneous to assume that we have solved all the problems of dwindling natural resources and conservation in the Soviet Union. Numerous critical articles on the subject tell of the still existing inefficiencies and difficulties in this essential field.

The most important cause of these continuing problems is the fact that some managers of industrial plants still believe that the country's natural resources are inexhaustible. They are quite wrong. The Soviet Union is indeed vast, its natural resources diverse and not completely explored. However, because of exceedingly uneven distribution, as well as certain historical and other factors, these resources are not available for use in all regions of the country. In many of these regions resources are scarce or their development is economically unfeasible at this time.

For example, most of the fertile black soil in the southern part of European USSR and in Western Siberia and

Kazakhstan is under cultivation. The density of cultivated areas is often above the optimum. This, in combination with general natural conditions, causes drought to occur, soils to be forcefully washed or blown away, and the progression of ravine erosion. True, these conditions are largely due to the fact that before the October Revolution most of the provinces of central European Russia were allowed to become overcrowded. Even now our main agricultural regions are plagued with troubles for a number of reasons.

Some of the most important industrial regions such as the Donets Basin and the Urals are experiencing acute water shortages. In the Donets Basin this is largely attributable to an insufficient amount of surface and underground waters; in the Urals, especially in the Mid-Urals, the water shortage is caused by the pollution of surface waters with industrial wastes which increase with industrial development of the region.

Forestry offers a striking example of the type of problems we face in the use of natural resources. A few centuries ago the entire northern section of European Russia with non-black soil was covered with dense taiga-type forests, but today not a trace remains in the entire North-West. These areas badly need afforestation. The largest timber cutting industries are found in the European North-East, along the banks of large rivers in some parts of Western Siberia and in the Altai and Sayan mountains and the Baikal area. These regions are cutting timber at break-neck pace while reforestation is far behind. At the same time vast areas of taiga in East Siberia and the Far East which are far from timber-raftering rivers and railroads could be put to better use.

Such regional shortages of natural resources demonstrate that even a country as large as the Soviet Union cannot allow unbridled use of its natural resources. The exploitation of natural resources in a socialist country should be based on the principle that resources will be mined only by scientifically sound methods, and that renewable resources will be reproduced on an extended scale after having been exploited as fully and effectively as possible.

Other causes of problems in conservation are: the preferable use of certain resources because of economic feasibility; industry and transportation's failure to convert to conservation methods quickly and extensively; and insufficient knowledge of the fundamentals of socialist exploitation of nature.

There was no alternative to the preferable use of certain natural resources in many regions of the USSR during the initial build-up of a material basis for socialism. Industry under tsarist Russia was extremely underdeveloped. Also, the Civil War of 1918-1922 brought about new devastation. The continuous economic blockade placed on the first socialist country by imperialist states forced the Soviet Union to rely on its own resources. For these reasons, the first five-year plans called for maximum exploitation of the most accessible and economically important natural resources. The economy was to be developed as rapidly as possible.

It is in this context that one should remember the development of the power industry by construction of the Dnieper and Volga chains of hydroelectric stations, dams, and water reservoirs. Though greatly contributing to the industrial potential of the country, these constructions were not without consequences which were inimical to the environment. Water reservoirs which covered millions of hectares of meadows and forests were especially destructive. The radical change in water conditions also seriously damaged the fisheries in the Volgo-Caspian basin.

Another example of unfavourable consequences caused by the hydroelectric industry is found in the Sea of Azov. The regulation of the water flow from the Don and Kuban rivers—necessary for the industrial water supply and irrigation of the rivers' basins—reduced the flow of fresh water into the Sea. The water exchange between the Azov and Black seas was disrupted causing salty water to flow into the Sea of Azov. As a result the latter's fauna and fisheries were damaged. Today remedial measures are being worked out.

Still another example is the Aral Sea. This inland body of water is fed by two large rivers from Central Asia, the Amu-Darya and the Syr-Darya. The sources of these rivers are in mountainous glaciers and the rivers themselves flow through deserts where their waters are used to irrigate oases. These oases which are used for the cultivation of valuable types of cotton gradually expanded by taking in increasing amounts of river waters. While this process was confined to the flood-lands, the water balance of the Sea did not change appreciably and its level remained fairly stable. Once, however, the Karakum Canal was built, and desert lands far from the valleys began to receive water for irrigation, the situation quickly changed. The influx of river water into the

Aral Sea began to decline, the Sea level dropped, and the Sea area was diminished. The shores of the Sea are now retreating, laying bare salted waste lands where desert erosion is at work. When the vast deltas of the rivers started to dry, the ground waters mineralised and the water-thirsty vegetation began to degrade. The economy and quality of life here have been tangibly damaged. The fisheries have been almost completely destroyed and the supply of fodder and drinking water for animal husbandry has deteriorated. Measures to combat desertification, which would not hamper the cultivation of cotton and other irrigated crops that are necessary to the country, are badly needed.

The obvious lesson to be learned is that whenever man invades nature, even for the most urgent economic needs, a comprehensive analysis of possible consequences, an advanced scientific forecast, and effective measures to offset or alleviate any detrimental consequences are obligatory.

Industry and transportation need to undergo extensive and rapid modernization, even radical change, if nature is to be protected. This is especially true in the context of today's revolution in science and technology. Today it is not only the list of natural resources to be exploited that is growing, but also the amount of industrial and other wastes dumped into the environment. Society's impact on nature is dramatically increasing. Measures to combat the almost global environmental pollution and to reproduce on a widening scale consumed natural resources are more and more needed.

This will require new technology and new protection tools. Industry and transport must be geared up as quickly as possible to put into effect conservation measures. Any modernization, however, will require funds and efforts. At times these conservation measures may not be in keeping with current industrial economic plans, thereby making conservation efforts more difficult. Despite these difficulties the overall objective of socialism in the use of natural resources remains the unconditional protection of the environment as specified in appropriate resolutions made by the Party and the government.

In this context comprehensive scientific and technological projects are of special importance. These projects include working targets for major problems in conservation and the intelligent use of natural resources.

These targets are:

- the development of scientific and technological principles

and of a set of measures for the improvement of water resources' use and protection;

- feasibility studies for diverting some of the Northern and Siberian river flows into the Volga River basin, Central Asia, and Kazakhstan;

- the development of new effective methods and facilities for the purification of liquid wastes;

- the development and implementation of more sophisticated techniques and equipment for the protection from air pollutants;

- the development and implementation of a sophisticated system of observing, controlling, and estimating the state of the environment;

- the development of an extensive set of scientific and technological measures for the prevention of negative effects on the environment caused by economic growth.

All of these activities are proceeding on a wide scale and have given tangible results. However, scientific and technological measures must be based on fundamental theoretical research, which at this time need significant improvement. Science must share the blame for not having foreseen the detrimental effects of human interference in natural resources. This censure is justified since at an earlier time of socialist construction when the Soviet scientific community (especially the academicians) were called on to identify natural resources and to develop plans for their use, the scientists rose to the occasion. At that time numerous large-scale inter-disciplinary expeditions with the aim to identify natural resources and to develop the productive forces of the Urals, Kazakhstan, Central Asian republics, Western and Eastern Siberia, and the Far East were being conducted by the Council on Productive Forces under the USSR Academy of Sciences. These expeditions were important steps in developing Soviet science and contributing to the progress of many institutes, branches of the USSR Academy and of research institutes under the Academies of Union republics.

Later, Soviet scientists were actively engaged in developing for the re-making of nature on a large scale. Occasionally their voice was decisive. They rejected what seemed technically and economically a rather promising idea of creating a large low head dam in the lower Ob for a powerful electric station. The scientists believed the dam would be detrimental to the entire West Siberian Plain, reduce the drainage of the plain still further, and facilitate

swamp formation. Immediately afterwards the West Siberian gas and oil field was discovered.

Soviet scientists faced a much more difficult problem in predicting the future of the Aral Sea and the unfavourable consequences its drying would have on the environment. The future decisions should allow for the development of irrigational agriculture and water supplies to factories, and settlements in the basins of the Amu-Darya and the Syr-Darya. The conflicting demands for the water resources should thus be resolved.

Still more controversial is the diversion of northward flowing rivers southwards, both in European USSR (Pechora-Sukhona-Kama-Volga) and, even more so, in Western Siberia (Ob-Irtysh-Kazakhstan-Central Asia). The complexities of the problem include: the future of the basins of the Sea of Azov, of the Caspian Sea, of the Aral Sea, and of Lake Balkhash; the feasibility and possible consequences of draining some water from the basins of the Irtysh and the Ob; the filtering losses of water along the immense canal in the Turgay "corridor"; the quality and amount of water to be diverted; its use in the steppes of Western and Central Kazakhstan and in the desert plains of Central Asia; the overall economic efficiency of the diversion, etc.

The fact that there are conflicting views voiced in the scientific community demonstrates that basic research is not yet prepared to solve the problems which arise from the exploitation of natural resources today. Indeed, though many natural sciences have been engaged in various studies of the environment, and of man's impact on it, in particular, for considerable lengths of time the true causes of many detrimental changes in nature, and the gist of the unfavourable impact of physical, chemical, or technical factors are not known to a sufficient degree.

This shortage of basic scientific knowledge has become apparent under scientific and technological revolution during which man has undertaken an especially active exploitation of a wide range of natural resources, produced new kinds of impact (such as radiation) on the environment, and polluted on an unprecedented scale with substances such as chemical toxins and plastics which are utterly foreign to the environment.

Therefore the contribution expected of basic (academic) science in the implementation of directives formulated in the

above decision of the Party and the government on protection of nature and in earlier decisions of this kind is to be quite substantial. All achievements of Soviet science should be used to the fullest for the conservation of nature. Furthermore, basic research in fundamentals of socialist use of nature should be understood as an urgent need. Ways to scale up such research should be determined.

In my view, the most important objectives of basic research in environmental fields are:

1. All-around optimization of the quality of human life by protecting and improving the properties of the environment.

2. Wasteless technology in industry and agriculture, and closed cycles of water consumption for the elimination of harmful wastes.

3. More rational use of natural resources, particularly of water and soil and biological resources, notably their protection, restoration, and extended reproduction.

4. Protection and preservation of the entire genetic fund of the biota.

The wide range of scientific disciplines to be involved in basic research to reach these objectives will require inter-disciplinary research. An important prerequisite for this is an ecological orientation of all activities in such projects.

Basic research should be carried out on an ever wider scale. More fields of science should be involved. Success will depend on close interaction between the sciences within the framework of inter-disciplinary projects. In this way, beneficial exchange of ideas and findings will be insured. There is no other way to approach the problems of the environment in a comprehensive and constructive manner. Such an approach is essential for the development of scientific fundamentals to serve as guidelines for the state and public in a socialist society.

## **METHODOLOGICAL PROBLEMS IN EXTENDING THE ECOLOGICAL APPROACH IN MODERN SCIENCE<sup>1</sup>**

One of today's major problems concerns the influence of scientific and technical progress on the environment (biosphere). The ultimate objective of such studies is to protect the environment and bring about its improvement from the point of view of the well-being of current and future generations. Basic forms of research that today are called "ecological" and that bear on the further clarification of rational forms of using the biosphere's resources and the protection and improvement of the environment should in principle be applied to all areas of modern science in mutually interrelated ways, for their common object of study is the natural environment as an integral whole.

### **THE GENERAL OBJECTIVES OF ECOLOGICAL STUDIES**

As a result of the revolution in science and technology mankind's interactions with its environment are becoming increasingly complex. Man's general influence on nature is greatly intensified through a growing exchange of matter and energy. This expresses itself in a growing utilization of natural resources and in increases in industrial and household waste products that are discharged into the environment. Nature's capacity for a spontaneous reproduction of intensely utilized resources and for a self-purification of the waste products that it receives is steadily

---

<sup>1</sup> *Questions of Philosophy*, 1978, No. 11 (in Russian).

declining. In both established and rapidly developing industrial regions one observes shortages of natural resources, declines in their reproduction, and a deterioration in their quality, as substances accumulate in the environment that exert a toxic influence on living organisms, including man.

It is important to recognize that at the theoretical level the complex set of problems that derive from the influence of the revolution in science and technology on society's interaction with nature are still insufficiently understood.

We believe that the principal objectives of basic research in this area are the following:

1. to optimize the conditions that govern the vital activities of populations by preserving and improving corresponding properties of their environment;

2. to effect as rapidly as possible a comprehensive shift of industrial and agricultural activities to technologies that do not generate waste products and rely on closed water utilization cycles;

3. to find rational forms of using natural resources and especially water, land, and biological resources, in ways that provide for their protection, renovation, and expanded reproduction;

4. to protect and preserve living nature's genetic fund.

The variety of scientific disciplines that to such fundamental studies call for a diversified complex of research activities, and for a maximal reliance of all disciplines on an ecological approach.

This requires a clarification of the meaning that is attached to the concept of "ecological studies" in the sense in which it is employed in the present paper.

## **ECOLOGY AS A GENERAL SCIENTIFIC APPROACH**

The evolution of the concept of "ecology" appears to have passed through the following stages.

1. It was Darwinism that produced an evolutionary understanding of living nature in the second half of the nineteenth century. It defined the initial interpretation of the concept of ecology as a science concerned with mutual interactions of the biota (living plants and animals) with its habitat. This meaning continues to be employed in biology at the present time and may be described as a biological interpretation of "ecology".

2. Marxism, which created a scientific understanding of the laws that govern social development, distinguishes between man and the remaining world of animals. It views man as a socio-biological phenomenon and human populations above all as social formations. In this way it placed boundaries on the sphere to which a bioecological approach may be applied in explaining the conditions of man's existence and especially the major characteristics of social life.

3. Recent studies of the substance of the present revolution in science and technology and of its influence on the environment have widened the concept of "ecology" and have led to the use by scientists of such terms as "human ecology" and "social ecology" (as well as other ecological terms). But these have been given meanings that are insufficiently clear. They must be made more precise by combining natural scientific and socio-economic approaches to studies of modern interactions among nature, man and society. Such a perspective on the problem draws attention to an objective process of "ecologization" of modern natural and social sciences. But it also defines methodologically grounded approaches to the ecologization of various sciences and their relationship to traditional scientific approaches.

The revolution in science and technology has greatly increased the complexity of society's relations with nature. In particular it has produced a sharp increase in anthropogenic influences on nature deriving from a more intensive utilization of natural resources and from society's further industrialization and urbanization. Aside from producing material goods this has caused a deterioration in the environment both through pollution and other perturbances and also an increasing shortage of natural resources. It is this that has led to the emergence of a wide social movement to protect nature, improve the environment, comply with more rational forms of utilizing natural resources, and provide for their reproduction. Throughout the world leading scientists have addressed themselves to these problems in a number of major works. At the same time numerous national and international scientific conferences and symposia were held on the ecological problems.

Thus, together with many other "ecological" concepts relating to mutual interaction between nature and society, the terms "human ecology" and "social ecology" have come to be widely used. Yet there is still no unambivalent

interpretation and no philosophical elaboration of their meaning.

To what extent is a particular use of basic ecological concepts in modern science justified from a philosophical and methodological point of view, and what more specific meaning should be given to these concepts?

In our opinion, a basis for an answer is found in the current wide use of the concept of "ecology" to refer to the relation of any object being studied to its natural environment. It is no longer possible, nor necessary, to limit the meaning of that concept to its original purely biological meaning, for that would compel us to nearly exclude altogether its application to man and to society. From the point of view of dialectical materialism the biological component of "human ecology" should only be viewed in connection with social factors. Yet questions relating to society's use of living nature and to the former's influence on the natural environment and its populations cannot be excluded from ecology in any sense of that word.

But the following question does arise: is it possible to view "ecology" in its present meaning as an independent science developing at the interface between natural and social sciences? I believe that from a methodological point of view such a position would be too simple, for it clarifies neither the concept's meaning nor the boundaries of ecological studies. Nor does it differentiate between the objects that are studied by various scientific disciplines. This is why it seems more correct to view ecology as a particular general scientific approach to the study of various natural and social objects comparable to the systems approach and the cybernetics approach. The objective of an ecological approach is to establish and study relations that exist between the objects that are studied by a particular science and their environment. It requires a knowledge of various sciences (e.g. biology, sociology, etc.).

Ecological approaches are made especially relevant by the revolution in science and technology. This is why the term "ecological approach" should be understood in the wide sense of an "ecological scientific thinking".

Such an understanding of ecology makes it possible to introduce a certain systemic element into the meaning of an "ecologization" of modern science. It also justifies the use of ecological studies not only in biology but also sociology, economics, and law as well as in relation to technologies. But

while different objects may be selected for such studies together with different technological processes and different social and economic evaluations and legal norms, and while different scientific methods may be employed, all aim at a common objective, namely the study of relations between the natural environment, on the one hand, and the biota, man and society, on the other.

A question also arises concerning the particular scientific discipline that is concerned with the environment itself, viewed as an aggregate of abiotic, biotic and technogenic components that are either altered or created by social activities. It is various relations between such an "organized" environment and the objects being studied by various sciences that establishes the substantive contents of ecological approaches. Even when these objects themselves are part of the environment constituting individual components within it that are studied by various disciplines, their aggregates and mutual interactions lend an element of integral unity to the environment and define a need to study the environment itself as the object of a specific science. In our opinion, geography is such a science, or, more precisely, such a system of sciences.

## **ECOLOGY AND GEOGRAPHY**

Strictly speaking, geography has always studied the environment taken as a whole (as a system) including its natural and anthropogenic (technogenic) components. This is only natural for the environment is marked by considerable spatial variability and it is precisely this property of geography that is of great ecological significance. And that is the reason why it would appear to be possible to view geographic studies of the environment as a necessary prerequisite for any ecological studies. But this should be stated more strongly: geographic science must develop a leading role in fundamental ecological studies of the environment, for more than other sciences modern geography is prepared for ecological studies on an inter-disciplinary basis. It has developed necessary means and methods, and above all has acquired an enormous volume of information concerning the natural environment and its natural resources, and also concerning the extent to which they are developed and exploited for economic purposes.

Beyond this in its studies of ecological problems of the environment geographic science relies on a well-developed system of sub-branches that are concerned with principles governing changes in the environment's components, the territorial location of population, the development of various economic sectors, the nature of their influence on the environment, and the conditions that govern human life. An important characteristic of geographic studies concerns the considerable possibilities of comprehensive approaches to the study of natural and social phenomena. It should be stressed that in the case of geographic science it is precisely in carrying out inter-disciplinary ecological studies that the full potential of a comprehensive approach may be realized. As for the contents of the major scientific branches of ecological studies in geography they are the following:

1. control over changes in the environment attributable to human activities (anthropogenic monitoring);
2. scientific geographic forecasts of the consequences of economic activities on the environment;
3. the anticipation, attenuation, and overcoming of natural catastrophes;
4. optimizing the role of the environment in the natural-technological systems created by man.

*Anthropogenic monitoring.* A system for monitoring and controlling all changes in the natural environment produced by man's economic activities is needed as a source of comprehensive information concerning the current state of the environment. Such information makes it possible to identify those regions that are most perturbed in that respect ("hot points"), to anticipate possible harmful changes in the environment, and to develop scientific forecasts of its future state.

Within such a monitoring system one should distinguish three major blocks: a bioecological (sanitation) block, a geoecological (natural-economic) block, and a biospheric block.

The role of the bioecological block is primarily to permit observations and control over the state of the environment from the point of view of its influence on the health of the population and its vital activities.

The functions of the second, geoecological (natural-economic) block concern observation and control activities over changes in those geosystems (including both natural and natural-technological ecosystems) that constitute the environ-

ment. It is particularly important to stress the interrelations and mutual interactions among these blocks of a monitoring system. It is only through the second block (the geoeccological one) that the indicators of the first (bioecological) can acquire the needed level of scientific validity and a scientific basis for spatial extrapolations. This is a very important proposition: unless it is applied, the indicators that are employed in bioecological monitoring systems will retain only local and empirical dimensions.

The third block of biospheric monitoring must serve observations and control activities over global background changes in the environment (biosphere), as well as an ecological evaluation of these changes. Its basic indicators must therefore convey generalized information concerning the state of the atmosphere, the hydrosphere, and the lithosphere.

Basic scientific research is needed to implement such a scheme for monitoring the environment. It is especially important to utilize new sources of scientific information, and particularly space research and automated information processing.

*The development of scientific (geographic) forecasts of anthropogenic changes in the environment.* At present this branch of scientific research activities forms an important component of national economic planning. Such forecasts are needed to establish rational approaches to the utilization of natural resources and to arrive at a correct planning of all measures relating to the protection of the environment. There above all they are needed to develop scientifically grounded programs seeking to achieve radical transformations of natural conditions: large-scale irrigation projects, plans for redirecting the course of rivers, large-scale influences on climatic processes, etc. All these forecasts must be based on the fullest possible information concerning the current state of the environment within the territories to which they relate and on knowledge of prospects for developing the economy (particularly of those sectors of industry, agriculture and transportation that will most transform the environment during the forecasting period).

*Natural catastrophes.* Some of these catastrophes (for example, hurricanes, torrential rains, droughts) occur in nature independently of human activities yet threaten human lives and produce substantial economic losses. Non-rational forms of development in individual territories and of

..

exploiting natural resources intensify the destructive effect of many uncontrollable processes—such as erosion and wind erosion, karst and thermokarst, sags and landslides, seli and floods, falling rocks and snow avalanches. Some of the uncontrollable natural catastrophes are directly attributable to anthropogenic causes, such as in territories that are abandoned following mining activities and agricultural lands suffering from secondary salinity and swamps.

Above all basic research should be concerned with the development of scientific foundations for forecasting natural phenomena, reducing the resulting losses, and also preventing the further development of such anthropogenic influences. Most natural catastrophes may be either overcome or else greatly attenuated through a diversity of measures relating to recultivation, irrigation and reforestation, and hydrotechnical and other engineering measures.

*Optimizing the role of the environment in mixed natural-technological systems.* This refers to overcoming or else attenuating as much as possible the unfavourable influences of various technical facilities and activities on the environment. A simple example is the maximal cleansing of a natural-technological system (a city, region, enterprise) from industrial and household discharges and wastes.

But the harmful influence of human economic activity on the environment is not limited to its pollution by toxic and other products: it extends to deep influences on the reproduction of natural resources, the development of elemental destructive processes, and other phenomena taking place in nature. It is of course not possible to limit economic activity as a whole. This can only be done on small territories, for example, in natural reservations. Accordingly, it is necessary to find forms of human production activities that not only exert a minimal damage to the environment, but, by influencing natural processes in a planned manner, also guide their development in ways that are favourable to man's vital activities. It is the task of ecological studies in geographic science to identify territorial structures of joint natural-technological systems (urban, industrial, agricultural, forest, recreational) in which the use of the most progressive forms of production activities makes possible transformations of the environment that are optimal from the point of view of the vital activities of human populations.

It is evident that ecological studies in geography must be

complemented by corresponding studies in geological, biological, technical and socio-economic sciences.

*Ecological studies in geological sciences (including mining)* complement geographic studies in all spheres of economic activity that relate to the assimilation of the mineral resources, of the lithosphere, to industrial, transportation, and housing construction activities in various geological conditions, and to efforts to avoid elemental catastrophes originating in processes taking place within the Earth's core.

*Ecological studies in the biological sciences* emphasize efforts to maintain the population's health and to preserve living nature's entire genetic fund, to develop new genotypes of plants and animals that are more stable and productive and also corresponding ecosystems, and to intensify activities in agriculture and forestry through the use of biological methods.

Biological studies concerned with the ecological foundations of human health should emphasize the essence of the toxic influences on man of various substances contained in industrial and household waste products, and the harmful influences of such physical irritants as noise, substances producing allergies and carcinogenic substances. Aside from establishing the direct physiological consequences and disruptions that are produced by such factors within the environment, a very large role is played by basic research in genetics concerned with the more indirect unfavourable consequences of a systematic operation of such factors on the human organism.

*Ecological studies of technological processes* are concerned with comprehensive uses of mineral raw materials and other types of natural resources, the organization of recycling in technological processes, closed cycles of water consumption by industries and households, and the most effective methods for purifying industrial and household waste products, including biological methods. The general objective of such studies is to establish the most rational and effective forms of industrial production and consumption of natural resources (with the help of goal-oriented technological processes) into the general energy and matter transformation cycles that take place within the biosphere.

The steadily growing material requirements of modern societies require further increases in the scale of natural processes and the development of new artificial processes. But all such measures must be based on a comprehensive

knowledge of corresponding principles governing natural processes. This defines the following major branches of research in ecological studies of technological systems: the development of new methods for purifying waste products, complex forms of utilizing industrial raw materials, the reprocessing and disposal of waste products, and the development of technological processes producing little waste.

*Ecological studies in the socio-economic sciences.* Today it is not possible either to engage in scientific studies of any ecological problem or to effectively apply their findings to social and economic practice without a comprehensive consideration of socio-economic aspects. An effective protection and improvement of the environment requires a planned as well as rational utilization of natural resources. But in such a context in order to be concrete the concept of "rational utilization" must also include social and economic criteria. This points to the need to develop fundamental scientific principles governing ecologically effective forms of state regulation of forms of nature-utilization. Within such wider principles economic principles play an important role.

There is an urgent need for major efforts to further improve the activities of states in developing and utilizing natural resources and in protecting the environment. These efforts must be based on current ecological studies, and especially those that include social and economic dimensions. While a number of corresponding agencies have already been established in the Soviet Union that have been assigned appropriate responsibilities basic research is needed to guide both the activities of existing organizations and their further development.

\* \* \*

In concluding I again wish to emphasize that while ecology or more specifically the ecological approach to the study of phenomena has originated and developed as a special discipline within the biological sciences it has now become a general scientific approach.

## CONSTRUCTIVE GEOGRAPHY AS THE SCIENCE OF GOAL-ORIENTED TRANSFORMATIONS AND REGULATION OF THE ENVIRONMENT<sup>1</sup>

In 1960, in preparing for participation in the work of the next international congress, the USSR's Geographic Society published a book entitled *Soviet Geography. Findings and Problems* (Geografiz, Moscow). The following general propositions were presented in its Introduction.

1. The true general problem of geography, which is one of the world's oldest sciences, has always been and continues to be *the study of nature, population, and economy* on the territory of particular countries, their different parts, other countries, and the Earth as a whole. The scientific findings of geographic studies have always been widely applied in practical activities, in finding and utilizing natural resources, in bringing about the economic development of a territory, in the rational location of industrial enterprises, human settlements and transportation lines, and also in the development of productive forces in various regions and countries.

2. As the world's population continues to grow and its material needs increase, as does social production, including the powerful capacities of modern technology, these general problems of geographic studies neither vanish nor become simpler. In fact they become increasingly complex since the composition of natural resources employed by human societies becomes more diversified and the extent to which its economic activities influence the environment increases.

---

<sup>1</sup> *Transactions of the USSR Academy of Sciences, Geography Series*, 1972, No. 3 (in Russian).

3. This is why modern geography is a *science concerned with transformations*. Its primary objects are the lands and countries long settled by human populations, possessing an altered nature, a dense population, and a diversified well-developed economy. But today modern geography's main problem throughout the world is no longer to facilitate a pioneering settlement of new lands and development of their natural wealth, but rather a comprehensive scientific support for vast efforts relating to a diversified and increasingly intensive utilization of already discovered natural resources and a transformation of the nature and economies of already developed regions and countries.

4. In order to make possible sufficiently precise and comprehensive geographic studies of territories and of corresponding phenomena that are commensurable with the needs of modern practice, and in order to provide valid explanations for emerging geographic properties, based on modern scientific conceptions, it is necessary to acquire a knowledge that is far deeper and diverse than earlier, and to master many of the newest specialized methods in both field research and laboratory research. All of this taken together cannot simply rely on the framework of any one discipline and lies beyond the capacities of a single specialist. At the present stage of geography's development the single science that existed earlier is becoming a system of sciences while the individual universal scientist possessing encyclopaedic knowledge is replaced by the collective labour of many specialized geographers organized in accordance with an integrated plan.

5. This is why the present state of geography in the USSR, as well as in other countries, rests on the emergence and development of an entire system of scientific disciplines that are replacing the earlier single geographic science. This is a complex and contradictory process that is still far from having run its course. It is proceeding through a struggle of the new against the old along many dimensions.

In 1966 in an article entitled "A Constructive Geography: Goals, Methods and Results", *Transactions of the Geographic Society* (Vol. 98, No. 5), I attempted to forecast the course of major elements of a scientific approach in the impending stage of development of geographic science. The following question was raised in that article: Should not the three closely interrelated approaches listed below be viewed as the

most important ones for the development of geographic science in the immediate future?

1. The development of a theory and of scientific programs of a planned transformation of nature needed for the further effective utilization of natural resources.

2. The development of a theory and creation of regional models for the most rational location of social production activities and of productive forces in developing the economies of individual countries and of their major territorial subdivisions.

3. The study of the laws that govern the migratory movements of populations and the development of human settlements in varying geographic conditions, and the drafting of scientific programs of modern urban development whose aim is to create the most favourable possible conditions for human life.

An answer to that question was given quite rapidly. It was provided by the very course of actual developments, which led to a wide social discussion of the problem of "Man and the Biosphere", or, stated still more comprehensively, of "Man and the Environment". The substance of these problems is quite simple.

The natural environment is a necessary basis for mankind's existence. It serves as the source of energy and materials employed in man's vital activities which are required for the existence and development of societies at all their stages—primitive, slave-owning, feudal, capitalist, and socialist. In the course of time, as world population increased, as its needs grew and production activities developed, the overall volume of energy and the quantity and composition of materials extracted by man from nature as well as of waste products continuously expanded. At the present time such exchanges of materials and energy between nature and society have reached such impressive dimensions that human production activities have become a major global factor in influencing nature that is comparable to geological or cosmic forces.

The extraction of energy and of materials from the environment that is carried out by society as well as their return in altered forms (in the form of industrial, household, and other waste products), together with direct anthropogenic influences on the course of natural processes, 'disrupt the equilibria of dynamically balanced natural material and energy cycles. But in the course of its long evolution nature

has acquired a capacity to restore disruptive natural processes and balances. As a result, up to a certain level of influence, the natural environment taken as a whole has been able to withstand anthropogenic disruptions, even though *local* irreversible changes had begun to take place a long time ago. Following the Industrial Revolution in the last century the general intensity of society's influence on nature began to exceed its restoration potential on many large areas of the Earth's surface. This has led to irreversible changes in the environment on a *regional* rather than merely local scale.

Today at a time of revolutionary developments in science and technology and of rapid rates of industrialization and urbanization society's influence on the environment has reached an unprecedented intensity and scale, while retaining a tendency towards a still more accelerated development. This produces a danger that regional shortage of various types of natural resources will develop, and that irreversible environmental disruptions and destructive elemental processes of a *global* character will occur.

A real threat has thus emerged of an irreversible disruption of natural *material-energy* balances on a scale that may impede the continued supply of certain types of natural resources to society.

The problem of preserving environments that are favourable to social life is becoming equally urgent. The essence of that problem concerns the fact that the prolonged evolution of man's biological characteristics, which are marked by an exceptionally complex combination of functions, has resulted in a highly perfected adaptation of his organism to the biosphere's physical and chemical conditions, i.e., to the natural environment. In particular, man has proven to be endowed with a well-developed capacity to withstand relatively diverse natural changes in environmental conditions produced by cosmic, meteorological and geographic factors.

By developing his material culture man has greatly enhanced this ability. As a result modern man confidently withstands not only the harsh cold of long Arctic nights, the heat of the tropics and the exceptional dryness of desert regions, but is able to live, for limited periods of time, at great depths within the ocean or in distant regions of outer space. '

Yet the very same man—as a specific biological species—is unable to achieve a complete well-being in situations in

which fundamental disruptions are taking place in the biosphere's natural properties as a result of society's progressive urbanization. For while modern man has surrounded himself with many remarkable objects of urban comfort his existence takes place in artificial environments that are in many ways incompatible with his biological properties. This is also why after many striking victories over numerous traditional illnesses that had at one time depleted the population of many countries (for example, the plague and cholera) and after achieving a substantial increase in life expectancy, modern medicine has encountered many new types of illness that originate primarily in urbanized forms of living, such as psychoses, neuroses, and chronic disruptions of cardio-vascular activities.

This is apparently the reason why very strong impulses—one may say primitive biological impulses—guide the persistent striving of modern urban residents towards natural surroundings. It is there that they seek to find health-restoring sources for regaining the strength that urban environments undermine.

Such impulses lead large numbers of urban dwellers to undertake hiking expeditions, visit "green" recreation zones and health resorts, and cultivate domestic plants within their urban dwellings. Yet the urbanization of modern man's life is continuing to develop on an increasing scale, and the many efforts that are intended to attenuate its negative biological consequences by no means always succeed. Thus in this sphere of his existence modern man is also meeting new and extremely pressing problems.

This leads to consider the following general question. Which of the currently existing sciences or systems of sciences is able to assume responsibility for a fruitful theoretical and practical development of all the complex and interrelated problems that are so vital to the further existence of human society, concerning the further rational exploitation of the Earth's natural resources and the preservation and goal-oriented transformation of the natural environment? The answer was suggested by the preceding exposition. This is *constructive geography*, which in our age of unprecedented scientific and technical progress must develop into an entirely new science as it addresses itself to such a large global problem. Already today it should be called the science of *a planned transformation and regulation of the environment* for man's continued existence and development.

In the article mentioned earlier, entitled "A Constructive Geography: Goals, Methods and Results", I had mentioned that the entire preceding course of development of modern geographic science has prepared it for fruitful work in precisely such a direction. An enormous volume of information has been accumulated concerning natural conditions, natural resources and their use for economic purposes. As its development proceeds geographic science currently relies on an entire system of branches and adjoining disciplines engaged in the study of the general principles that govern changes of individual components of the natural environment (for example, of the climate, waters, soils, vegetation covers, and the animal world), as well as the development of various economic sectors and of population. Finally, geographic science possesses the synthetic (integrated) approach to natural and social phenomena that is especially needed for successful scientific studies of the new problems.

It is very important that the theoretical foundation of the modern constructive approach in geography is the concept that there is a close interlinkage and interaction among all components of the natural geographic environment which is becoming especially complicated as a result of their utilization for economic purposes. It is well established that the influence of technical means on any environmental component produces complex chain processes that cause changes within them and influences their use for economic purposes. Yet the existence of specific "governing mechanisms" within the complex and dynamic systems of natural-geographic structures, which control internal linkages (both forward and backward linkages) among various components of the environment (for example, the thermal regime at the Earth's surface, a territory's water balance, and the biological productivity of ecosystems) provides a basis, first, for regulating internal linkages up to a point by achieving specific changes in particular components (the climate, water, soils, vegetation covers); and, secondly, for forecasting such changes.

One should not, of course, minimize the difficulties that confront the further development of the new constructive approach in geographic science and its actual transformation into a science of goal-oriented changes in and regulation of the environment. These difficulties primarily concern the need to shift from the usual qualitative and descriptive ge-

ographic characterizations and studies that were so traditional in past stages of geography's development to quantitative ones that are substantially more precise and that possess a concrete constructive technical and economic content. In order to obtain such characterizations new research procedures and calculations must rely on modern mathematical, physical, chemical and biological approaches. In addition, it is necessary to develop a number of new theoretical and methodological branches of geography that draw more closely together (and sometimes even merge) geographic approaches to the phenomena being studied with physical, chemical, biological and economic approaches. In other words, there is a need not only for the further development of traditional branches of geographic science but also for a deep reorganization of these branches as well as of many traditions of our usual geographic way of thinking.

This is of course entirely feasible. And a leading role in the further development of geographic science will naturally be played by the new young generation of geographers. For our part we, the representatives of the older generation of geographers, must show them these approaches, persuade them of their promise, and motivate them to engage in selfless work within the new branches.

In my opinion the concrete, particularly relevant branches of modern geographic studies that bear directly on the problems of man's interaction with society and the environment include the following:

- the further identification of the natural resources that are needed for society's production activities, their rational utilization and economic evaluation;

- the study of elemental natural phenomena and the development of means for forecasting them, actively influencing them and devising forms of protection against them;

- studies of the influence of production activities in modern societies on the environment, as well as of major types of such influences and of the intensity of corresponding changes;

- studies of transformations of the environment that permit a rational exploitation of natural resources and make it possible to overcome or attenuate negative anthropogenic changes and create favourable conditions for human life;

- studies of ways to protect the environment in order to

permit still further studies as well as its utilization for recreation and other purposes.

Increasingly current geographic studies in the USSR are turning to the development of these topical problems. In doing this they are effectively transforming geography into a new constructive science concerned with a goal-oriented transformation and management of the environment to serve present and future generations.

**II.**  
**STUDIES OF NATURAL ECOSYSTEMS**  
**(LANDSCAPES) AND OF THEIR**  
**ANTHROPOGENIC TRANSFORMATION**

---



# THE MATERIAL CYCLE WITHIN MAJOR TYPES OF NATURAL ECOSYSTEMS OF THE USSR<sup>1</sup>

(written jointly with Yu. A. Isakov and D. V. Panfilov)

The intensive development of biogeocoenotic studies, together with their great diversity, not only produce a rapid accumulation of information concerning natural ecosystems but also pose many new problems in the geographic and biological sciences and encourage new approaches to the solution of traditional problems. An important class of such problems concerns the typology of natural ecosystems as one of the initial steps required by a more general systematization.

A well-established scientific typology of natural ecosystems does not yet exist, even though there are many approaches to that problem that are largely based on systematizations of descriptive geographic (geobotanic, soil-geographic, and physical geographic) data. Such efforts have made it possible to identify major types of existing natural ecosystems and to establish their physiognomic characteristics. In recent years these have been increasingly supplemented with data on the level of biological productivity of various natural ecosystems, which lend a measure of quantitative specificity. But this does not yet permit the further development of a typology of ecosystems.

---

<sup>1</sup> *Transactions of the USSR Academy of Sciences*, 1972, No. 2, (in Russian). This article is a short version of the presentation of I. P. Gerasimov, Yu. A. Isakov, and D. V. Panfilov to the Conference on Current Problems of Biogeocoenology and the Findings of Biogeocoenological Field Station, held in Leningrad in December 1971.

Aside from a descriptive basis a comprehensive typology of natural ecosystems must be based on the functional characteristics of internal processes, and in particular of the material cycle that takes place within ecosystems. Of course this raises many difficult problems that call for appropriate detailed experimental observations. But a number of steps have already been taken in that direction (cf., the studies of L. Ye. Rodin and N. I. Bazilevich, 1965; L. Ye. Rodin, N. I. Remizov and N. I. Bazilevich, 1968). Still one should not overestimate the significance of the data that have already been obtained. For example information concerning the general biomass of various ecosystems and their productivity as well as concerning the biomass of individual components is insufficient to characterize the internal material cycle within these ecosystems. Its correct interpretation usually requires an additional functional (genetic) analysis of the corresponding role of various ecosystems components.

Just the same there is an urgent need today to develop a typology of major natural ecosystems on the basis of available indicators of the internal material cycle and of the corresponding functional role of major components. Above all it is attributable to the far-reaching scope of intensive anthropogenic transformations of natural ecosystems that radically disrupt natural patterns of material cycle and to the diverse and often lethal consequences of these transformations. This is why efforts to accurately forecast the consequences of anthropogenic influence are now becoming one of the leading scientific problems. But that requires a clear understanding of the essential nature of fundamental processes, and especially of the natural material cycle that takes place in various ecosystems. The enormous gaps that still exist in our current knowledge of this type of cycle must be overcome by various hypotheses and working models. The result of past experience in developing such models is presented in the form of several generalized propositions.

1. One of the most important indicators of the general character of the internal material cycle taking place within natural ecosystems concerns the *type* of cycle. All natural ecosystems may be divided into three major groups in terms of that indicator, namely, autonomous (independent), transitory (dependent) and accumulating (subordinate). In spite of the novelty of this terminology that classification is relatively traditional, for it corresponds to the most general physico-geographic as well as biogeochemical schemes. In

particular autonomous (or independent) ecosystems should be identified, in our opinion, with *zonal flat interfluvial* or watershed formations; transitory or dependent ecosystems with *intrazonal* formations on slopes that develop on the basis of transitional flows of materials; while *accumulating* or subordinate ecosystems may be identified with *azonal* accumulating formations located in depressions. That correspondence makes it unnecessary to comment further on such a subdivision which seeks to associate particular types of material cycle within ecosystems with the utilization of materials that are formed as a result of wind erosion and soil formation (autonomous and independent ecosystems); dependent on a selective interception of materials within transitional migration flows (transitory or dependent ecosystems); and, finally, subordinated (frequently unwillingly so) to the utilization (accumulation) of materials in terminal accumulation reservoirs (accumulating or subordinate ecosystems). One should merely note that the observations that follow refer to the first group of natural ecosystems, i.e., to autonomous (independent) systems.

2. When they develop optimally, *autonomous* (independent) natural ecosystems represent formations in a state of moving equilibrium in relation to the environment, i.e., formations that attain a climax. Such a state is the outcome of a prolonged evolution (in terms of geological time) of each type of autonomous ecosystem. But the existence of an apparently stable equilibrium does not at all imply that autonomous ecosystems have achieved a level of development beyond which they cease to evolve. As a result of varying environmental conditions within which such ecosystems exist and also in view of the nature of their biota which reflects their entire preceding course of evolutionary development, they possess *varying degrees of closure*, i.e., of autonomy with regard to the material cycle. The degree of closure that they possess, that is their ability to utilize substances entering to the ecosystem more fully without losses (external outputs) or excessive internal accumulation in the form of inert and utilized products, may serve as an important indicator of the general degree of perfection of the internal organization of an autonomous ecosystem. As will be shown below, different types of contemporary natural ecosystems are characterized by differing levels (measures) of closure, i.e., by substantial differences in levels of organization.

3. Aside from possessing various degrees of closure with regard to the material cycle autonomous natural ecosystems may also be characterized by other integral and differential indicators relating to the internal material cycle. Let us note particularly the *intensity or velocity of material cycle*, which may be established in terms of the ratio of the entire mass of the yearly biological production of a given ecosystem to its total biomass. Clearly, the smaller this magnitude will be, the greater will be the delay of circulating substances within the ecosystem that may result in their temporary conservation in some particular form. Conversely, an increase in that indicator points to a more rapid or more intensive material cycle, i.e., to a greater dynamism for the corresponding ecosystem. It should be noted that this integral indicator can and should be supplemented with such differential indicators as, for example, the ratio of the yearly increment in the green mass of plants to the general increment in phytomass; the ratio of the yearly litter to reserves of ground cover; and others. A juxtaposition of such differential indicators of intensity of material cycle with each other as well as with the integral indicator provides important specific characteristics for various types of ecosystems.

4. An important general indicator of internal processes and ecosystems is provided by the *structure of material cycle*. This may be reflected by a variety of characteristics of ecosystems and of different indicators. Let us note three that are most general, and which may be called completeness, state of balance, and the residual productivity of material cycle.

The first of these—*completeness*—may be characterized by the extent to which the entire organic mass produced within the ecosystem is utilized for its own functioning. It is well known that the most important form of expending organic matter within any ecosystem in the process of its functioning is its use for the respiration of the entire biota constituting the ecosystem. This is why one may view as the most integrated measure of completeness of the general structure of cycle the extent to which the yearly increase in biomass is expended on the respiration of living organisms—plants and animals entering into the ecosystem. In the case of ecosystems that are in a state of dynamic equilibrium with their environment such a measure must be an equilibrium measure, i.e., a hundred per cent (zero) one. If, on the other hand, the ecosystem produces somewhat more biomass than

is needed for the respiration of its own biota, then the structure of the internal material cycle is incomplete. This appears to take place only in the case of temporary succeeding ecosystems that have not yet attained an equilibrium at their climax.

The second structural characteristic of the material cycle within ecosystems has been called the measure of its *balance*. In its most integrated form this may be expressed in terms of the ratio of that ecosystem's primary and secondary biological production. High values for such an indicator point to the presence within the ecosystem of primary materials that are little used or else used only slowly in the course of the further material cycle, while lower values point to a more effective structure of cycle within the ecosystem reflecting a harmonization of the rate of output of primary production and that of its subsequent consumption and transformation. There again that indicator expresses the general level of the given system's organization.

Finally the *residual productivity* of the internal material cycle refers to the general ratio of the mass of living biota with dead organic materials accumulated within the ecosystem. Such dead organic materials may be unneeded ballast within the ecosystem, that is being accumulated but not used very much or at all. This is true for example of peat in the case of oligotrophic moors (high moors). But in many other cases the dead organic materials produced and accumulated within an ecosystem may represent quite an important reserve of needed nutrients or other substances. That reserve, which is temporarily taken out of cycle, as it were, is employed by the ecosystem only periodically, at times of crisis in its existence. It then plays the role of an insurance fund providing for the ecosystem's self-support. An example of such a reserve is provided by covers of dead leaves or reserves of humus in soils.

5. There is no doubt that in order to characterize the internal material cycle taking place within autonomous natural ecosystems (and also in dependent and subordinate ecosystems) as well as the major functions of corresponding components numerous other indicators may be used, both of the integral and of the differential type. But it is not the aim of the present communication to survey all such indicators. In characterizing major types of zonal ecosystems, in the USSR only the limited system of indicators that have been mentioned will be employed, together with (for purposes

of clarification) some additional qualitative characteristics.

6. *Tundra ecosystems* are subjected to significant deficiencies in heat and relatively favourable humidity conditions. Because of the briefness of warm seasons and especially of low soil temperatures and the continuous presence of gleys (tundra gley soils) their total phytomass is not large. So is the yearly production of phytomass, especially of green mass. As a result there is a low intensity of material cycle, whose structure is marked by a perceptible residual accumulation. As a result its primary production is regularly underutilized and an accumulation of undecomposed plant remains takes place in the upper layers of most soils. Such a formation of peat points to the loss from the biological cycle of a significant volume of organic substances and of associated biogenous elements. This appears to point to an insufficient evolutionary refinement of tundra ecosystems, which may be attributable to their relative youth, in absolute geological terms: they appeared on the Earth's surface only during the Pleistocene (second half), and were formed from biota components that were still insufficiently adapted to the new situation.

7. *Ecosystems of taiga (dark coniferous) forests*. In spite of the very large total phytomass that is basically formed by the timber and needle reserves over many years, the yearly increment of green mass in such systems is relatively small. The total zoomass in dark coniferous forests is also usually small: it is primarily represented by saprophages, which together with bacteria and mushrooms participate in the processing of plant remains on the surface and in upper layers of soils. It is there that acidic products of decomposition develop that interact with the soil's mineral components and stimulate its decomposition (podzolization). Because the presence of shade in such forests and cold soil temperatures reduce the rate of destruction of plant detritus, while the absorption capacity of podzol soils is low, plants, in their turn, are unable to fully utilize the minerals that are produced by the decomposition of organic matter. As a result many materials, including biogenous materials, are washed into subsoil tables in the form of organic mineral compounds. By entering sub-surface waters they are lost by the ecosystems. The low intensity of material cycle and its unfavourable structure (a very large accumulation of wood) as well as large losses of substance in autonomous conditions again point to an insufficient evolutionary refinement.

This is possibly associated with the relative youth of such systems, in absolute geological terms, which have developed in the lowlands of the USSR only recently. Perhaps this is the reason why taiga ecosystems tend to degrade very easily in natural conditions and to be replaced by other ecosystems, even though the latter may be temporary, such as, for example narrow-leaved forests.

8. *Broad-leaved deciduous forest ecosystems* possess a greater phytomass than dark coniferous forests. They also produce a far greater volume of green mass. The total zoomass of such forests is very large. Animals make intensive use of primary output during many months of the year, partly in the form of green products, but largely of litter. Together with large numbers of bacteria and mushrooms they bring to mineralization the substances synthesized by plants. Grey and brown forest soils are formed that are rich in clay minerals. Because they are so abundant in corresponding soils biogenous substances are largely retained in the soil's absorption complex and are again utilized by plant roots. In this way they do not leave the internal cycle sphere of the entire ecosystem. As a result the material cycle in broad-leaved forests is largely closed. This is reflected in the low intensity of podzolization, even though it does occur occasionally, particularly in regions possessing a more humid climate (in acidic grey forest soils). Normally grey and especially brown soils of broad-leaved forests contain substantial reserves of nutrients that are employed not only by fully-grown trees but also by bushes, young trees, and grasses.

9. *Ecosystems of grass steppes* are characterized by a lower volume of general phytomass, but their increment in green mass is almost the same as in those of broad-leaved forests, while the overall increment in phytomass is often even higher. Their zoomass is large and animals make intensive use of the green parts of plants, their roots and plant detritus. As rich black soils develop within the soils of such ecosystems an enormous reserve of nutrient substances accumulates. These remain for long periods of time in rich layers of humus and eventually enter into biological circulation through plants possessing deep root systems, as well as through the activities of rodents, especially marmots and gophers. While the presence of such important reserves of biogenous substances does attenuate the intensity of the overall material cycle it also serves as a major stabilizing factor for

•

corresponding subsystems, making it possible for them to survive extreme conditions of periodic crises within the environment (especially droughts).

10. The functional structure of *dry steppes* ecosystems is generally similar to that of grass steppes, but their total phytomass and their yearly production is smaller, and animals utilize the green parts of plants less intensively, while the mineralization of organic substances proceeds more fully. A low level of precipitation, the dryness of the air and of the upper layers of the soil reduce the vital activities of plants. Given an intensive processing of primary biological production this leads to an accumulation of surpluses of mineral compounds within the soil. As a result such soils (chestnut soils and saline complexes) are markedly alkaline.

11. *Desert ecosystems* in the USSR are highly diverse, but the psammophytic and clay-loess ecosystems that are characteristic of desert zones possess a number of common attributes. While the total phytomass and production of green mass in these ecosystems is low, a significant part of their phytomass consists of lignified plant tissues representing both sub-surface and surface plant organs. Especially in the southern deserts animals are significantly active throughout the entire year. Their zoomass is relatively high, and their systemic composition and adaptation greatly vary. This is why desert animals utilize the limited primary production of phytomass very intensively, and together with bacteria, account for their nearly full mineralization. As a result there is very little humus in desert soils, although there are large volumes of biogenous substances. Because of insufficient humidity the latter cannot always be employed rapidly by plants. Together with the dry climate this contributes to an accumulation of large reserves of substances in the soils, even in excessive amounts, that lead to their salinity (brown and grey-brown desert soils).

12. It may be seen from this survey that most surface autonomous natural ecosystems in the USSR, including those that are most productive, are marked by a *high degree of closure with regard to the material cycle*. The ecosystems of tundras and dark coniferous taiga regions are marked by clearly imperfect cycle processes that entail large losses of biogenous materials.

The rate of material cycle generally is highest in the ecosystems of broad-leaved forests and grass ecosystems of semi-arid regions in which favourable combinations of heat

and humidity provide for a diversity and high level of vital activities of plants, animals and bacteria, as well as a rapid synthesis of primary production and its transformation into secondary production. But there also exists an important and fundamental difference between these two types of natural ecosystems with regard to their reserves of biogenous materials. That reserve is small in the case of broad-leaved forests and large in steppes. This contributes to the latter's high degree of stability in relation to crisis phenomena within the environment (especially droughts).

Similarly, the internal organization of autonomous desert ecosystems is marked by a number of specific features.

13. *Anthropogenic changes in natural ecosystems* have taken place throughout the entire territory of the USSR. In some cases natural ecosystems are largely able to retain their natural specific features, while in other these have been completely transformed and have been replaced by anthropogenic characteristics. Anthropogenic changes in natural ecosystems and their replacement by secondary anthropogenic systems that are intensively exploited for economic purposes are primarily attributable to fundamental transformations in the vegetation cover in connection with the cultivation of specific crops, the wide utilization of grazing lands and fodder production for animal husbandry, and also the cutting of forests or else their intensive exploitation. In all such cases of anthropogenic influence the internal material cycle within natural ecosystems experiences various types of transformation.

In particular in the case of *tundras and most taiga territories*, extensive anthropogenic changes produce a certain intensification of biological material cycle. The vegetation cover and animal populations become more numerous and diverse, while the general biological productivity of such territories increases.

In regions of mixed coniferous and broad-leaved forests and also of broad-leaved forests anthropogenic transformations have produced a specific complex of forest, meadow, and field anthropogenic ecosystems that usually also possess a significant biological productivity as well as a number of other specific features relating to their internal material cycle.

Conversely, in *forest-steppe regions and steppes*, that is in natural ecosystems that are especially productive, a nearly complete ploughing of the land has impoverished the composition of plant and animal populations and has dis-

rupted natural processes of material cycle. As a result of their extensive utilization soils in these ecosystems have begun to lose reserves of biogenous materials that were accumulated over many centuries. This is attributable to both a decline in animal populations of the soils and a continuous removal of large volumes of materials produced by plants from agricultural anthropogenic ecosystems. Under intensive modes of agriculture this is neutralized by the addition of fertilizers into the soil, improvements in the level of agricultural technology and rational crop rotation practices. In cultivated highly productive ecosystems that have developed on the basis of grass steppes many new features are developing on the basis of internal processes, particularly with regard to the nature of internal cycle.

In arid steppe regions extensive animal husbandry is also leading to an impoverishment of natural ecosystems and a decline in their natural biological productivity. But in desert regions that are irrigated both overall biological productivity and primary production are increasing greatly. At the same time new types of cultivated oases ecosystems are developing on the basis of natural ecosystems.

14. Generally it may be said that *anthropogenic ecosystems*, which are characterized by a continual removal of substances, including biogenous materials, in the form of agricultural production, cease to be autonomous ecosystems and by their nature become subordinate anthropogenic ecosystems. The preservation of their natural productivity not to mention increases in such productivity require compensation in the form of fertilizers and other measures.

The replacement of natural ecosystems by anthropogenic ones has also produced other consequences. For example, the destruction of live covers highly adapted to local conditions results in intensive forms of anthropogenic water and wind erosion under which substances needed by plants are carried beyond the ecosystem's boundaries, soils are degraded, and the territory's water regime is disrupted.

It follows that in envisaging prolonged utilization and preservation of high levels of productivity of both natural and artificially created anthropogenic ecosystems man must assume responsibility for certain ecological functions. But it is important that this be based on a comprehensive knowledge of the entire dynamics of natural ecosystems, their internal material cycle and specific characteristics of their functioning, as well as of the principles that govern the

transformation of natural ecosystems into anthropogenic ecosystems. This points to the need for further extending efforts in studying physical, chemical and biological phenomena taking place in geographic landscapes that are primarily concerned with mutual relations between ecosystem environments and biotas and also with the internal material cycle in various types of natural and anthropogenic systems, cf., *Foundations of Forest Biogeocoenology*, 1964; *The Geophysics of Landscapes*, 1967.

## **Bibliography**

(in Russian)

- Isakov, Yu. A., Panfilov, D. V., *Zonal Characteristics of the Resources of the Animal World in the USSR*, in the collection: *Findings of Scientific Research, Geography of the USSR*, No. 7, VINITI, Moscow, 1969.
- Rodin, L. Ye. and Bazilevich, N. I., *The Dynamics of Organic Matter and Biological Cycles in Leading Types of Plants*, Nauka Publishers, 1965.
- Rodin, L. Ye., Remezov, N. P., Bazilevich, N. I., *Manual on the Dynamics and Biological Cycles of Phytocoenoses*, Nauka Publishers, Leningrad, 1968.
- Foundations of Forest Biogeocoenology*, Academician V. N. Sukachev and N. V. Dylis, D.Sc. (Biology), eds., Nauka Publishers, Moscow, 1964.
- The Geophysics of Landscapes*, Academician I. P. Gerasimov, ed., Nauka Publishers, Moscow, 1967.

# THEORY OF NATURAL ECOSYSTEMS (GEOECOBIOLOGICAL) AS A SYNTHESIS OF LANDSCAPE SCIENCE AND BIOGEOCOENOLOGY IN SOVIET GEOGRAPHY AND BIOLOGY<sup>1</sup>

Landscape science has long been a major discipline in Soviet geographic research. S. V. Kalesnik in 1961 defined it on in the Soviet Geographic Encyclopaedia as "the science of geographic landscapes. Its main objectives are the characterization of existing natural and cultural landscapes, the study of their structure, interrelationships, and the physico-geographic processes therein, particularly seasonal dynamics, the laws of evolution, man's influence on and possibilities of economic uses of landscapes".

The interpretation of a natural complex (geographic landscape) accepted today was originally put forth by V. Dokuchayev in his *On the Science of Natural Zones*, 1899, and then elaborated on by his followers, notably L. S. Berg, G. F. Morozov, G. N. Vysotsky and others.

L. S. Berg defined a geographic landscape as "a combination of objects and phenomena where the specific features of relief, climate, waters, soils, vegetation, the animal world, and, to a certain extent, human activity merge into an entity which is typically repeated in a given zone of Earth" (USSR's *Geographic Zones*, 1931, p. 5).

The Encyclopaedia fails to define "biogeocoenology". Nevertheless, it explains the concept of "biogeocoenosis" (Greek *bios*, life; *geo* earth; and *koinos*, common). Unlike

---

<sup>1</sup> *General Chemistry Magazine*, Vol. XXXIV, 1973, No. 5, (in Russian). The article is a report presented at the All-Union Conference on Biogeocoenosis Structure and the Effects of Man Thereon, Moscow, June 1973.

landscape science which, as already noted, has a long history. biogeocoenology was created and developed in the Soviet era. The concept of biogeocoenosis is believed to have been first mentioned in Academician V.N. Sukachev's article "The Evolution of Vegetation as an Element of the Geographic Environment in Comparison with the Evolution of Society" in 1940. However, a later article, "Fundamentals of Biogeocoenology Theory" which was published in 1947, seems to be of greater importance. Ye.M. Lavrenko and N.V. Dylis (1968) note quite accurately that "these ideas are the result of V.N. Sukachev's personal research and of the concepts that he acquired from V.V. Dokuchayev, G.F. Morozov, and V.I. Vernadsky".

One of the more recent definitions of biogeocoenosis is given by V.N. Sukachev: biogeocoenosis is that totality, over a certain area of Earth surface, of uniform natural phenomena (atmosphere, rocks, flora, fauna, microorganisms, soils, and hydrology) which features specific interactions between these components, specific interchange of materials with energy and the interaction of materials and energy with other natural phenomena; this is an internally conflicting dialectical unity which is in constant motion, or evolution (Chapter on "Basic Concepts of Forest Biogeocoenology" in *Fundamentals of Forest Biogeocoenology*, 1964, p. 23).

What then are the similarities and dissimilarities between these two major branches of Soviet scientific research? This is a logical question since the object of study in either case is a regular spatial combination of natural formations which is referred to as geographic landscapes (natural complexes) in the former case and as biogeocoenoses in the latter. Both landscape scientists and biogeocoenologist biologists have sought to answer this question.

In 1949 Sukachev published in *Voprosy geografii* an article entitled "Correlational Concepts of Geographic Landscape and Biogeocoenosis". He insisted that the "emergence of a new field of knowledge, biogeocoenology, in no way makes the existence of ... landscape science unnecessary" (p. 59). However, A.G. Isachenko, a well-known Soviet landscape geographer includes a chapter entitled "V.N. Sukachev's Biogeocoenosis Theory" in his book *Fundamentals of Physical Geography* (1953) and raised strong objections to Sukachev's contention that "landscape science and biogeocoenology are different disciplines". Isachenko tried to distinguish the fundamental concepts of the two branches of

research (landscape and biogeocoenosis) in "qualitative" terms only, i.e., as parallel systems of analogous concepts which may be regarded "from typological and regional viewpoints". According to Isachenko "the primarily 'typological' direction in landscape science is developed in biogeocoenosis theory".

To gain a better understanding of the questions involved, it is more necessary to examine the results of study and the direction of future research than to discuss and compare definitions (and there are many such definitions).

A discipline of geography, landscape science, has made significant contributions, above all, to a general typology of natural landscapes. The most important results have been expounded in *Geographic (Landscape) Zones of the Soviet Union* by Academician L.S. Berg. More recent field studies have relied on this book in developing a system of zone as well as other types of natural landscapes in the USSR. These studies were generally based on extensive geographic (including cartographic) material which was accumulated as a result of numerous field expeditions. As far as theory is concerned, special attention was given to establishing a taxonomic hierarchy of natural landscapes (from a zone to a facies) and to a methodology in describing them.

Research in landscape science has had a profound impact on how natural landscapes and biogeocoenoses are regarded. It not only confirmed the objective existence of natural and regular combinations (complexes) of natural formations and phenomena (natural landscapes and biogeocoenoses) in natural surroundings but also developed a method of study. This is referred to as *comparative geography*. The application of this method to geographic literature made possible the arrangement of an impressive body of descriptive material according to types of natural landscapes.

This area of study in landscape science is far from closed. Vast territories exist where nature has not been thoroughly explored. Moreover, science and practical needs require more detailed scrutiny of the descriptive characteristics and cartography of natural landscapes. Scientific description and study of landscapes changed by man as a result of his impulsive or planned activity is becoming more necessary.

Progress in landscape science is ever more dependent upon modern methods of exact science. Of special importance in this respect is the *increasing use of mathematics* in landscape science. This influence is felt in the mathematical *modelling*

of natural landscapes, thus far still at the experimental stage.

At the same time a general sophistication of traditional activities in landscape science has long been established in Soviet geographic science. A. A. Grigoryev and B. B. Polynov have created new and important branches of landscape science.

Grigoryev has significantly enhanced the view that "the core of interrelationships, interaction, and mutual causality of components in the landscape mantle of the globe is the exchange of matter and energy between its components" ("Theoretical Problems of Today's Physical Geography", 1964, p. 17). In a theoretical refinement of this concept, Grigoryev made an in-depth analysis of correlations between zonal types of natural landscapes and the amounts and ratios of heat and precipitation the landscapes receive. His findings were presented in a series of articles with the common title, *An Essay on the Analytical Characteristics of the Composition and Structure of the Global Landscape Mantle* (1937-1942) and in the book *Subarctics* (1946, 1956). His ideas were generalized (in coauthorship with M. I. Budyko) in a "Periodic System of Geographic Subaerial Belts and Global Zones". Modern experimental research in the *geophysics of natural landscapes* is based on Grigoryev's ideas. Above all, this research is seeking to uncover the *energetic essence* of phenomena and the processes therein.

Polynov has concentrated on the migration and cycle of matter (chemical elements) in natural landscapes. Accordingly, his line of research is generally termed as the "geochemistry of natural landscapes". A. I. Perelman and M. A. Glazovskaya have written the most complete and up-to-date account of the essence of this research.

It is important to emphasize that the above geophysical and geochemical approaches to natural landscapes represent a sophistication of the traditional methods of scientific research in landscape science. The descriptive, comparative geographic approach has been abandoned in favour of more dedicated experimental research. A better term would probably be "extended" and "refined" since the comparative geographic approach was still found to be necessary if the objects of experimental (stationary) research were to be chosen and the findings were to be scientifically and soundly extrapolated. In the framework of conventional descriptive landscape science, the latest geophysical and geochemical

methods have given rise to dedicated experimental disciplines.

This normal process of revising conventional approaches and research techniques was felt in biogeocoenology even sooner. As has already been noted, this line of research mainly originated from the geobotanical papers of V.N. Sukachev. From the very beginning, however, the research dealt with the processes and phenomena inside combinations of natural formations, i.e., in natural landscapes or biogeocoenoses. For this reason the new line of research has relied on methods of experimental (i.e. stationary) studies of biogeocoenosis by using descriptive material accumulated by geographic science only as a point of departure. Furthermore, following the general ideas of V.I. Vernadsky, this line of research has focused on the contributions made by living organisms (flora and fauna) to the formation and evolution of their natural surroundings. For the above reasons and also due to a reluctance to become a part of the conventional landscape science studies, biogeocoenology arose as a new science.

The main trends in Soviet biogeocoenology have been characterized in an article by Ye.M. Lavrenko and N.V. Dylis "Successes and Current Projects in the Study of Subaerial Biogeocoenoses in the USSR" (1968), and in other publications. Sukachev's and his followers' most notable achievement was the designing of sophisticated and very productive experimental (stationary) field studies of dynamics in various zonal types of biogeocoenoses in the USSR. These experiments have been carried out and continue to be conducted in different areas and on different scales. L.M. Nosova's "Survey of Soviet Biogeocoenological Research in 1970", published in *Ekologiya*, No. 1, 1972, describes these field studies. This work is mainly concerned with the composition and amount of living components (flora and fauna) in their dynamics. It also deals with biological productivity and trophic links in different types of biogeocoenosis. "

The unquestionable value gained from this research and its continuity with earlier research in landscape science is apparent in more recent studies undertaken in the USSR—notably in the biological productivity of natural landscapes or biogeocoenoses, their geochemical conjugation, and, finally, the energetic essence of processes there.

This article cannot cover or analyse the entire flow of

Soviet scientific information concerning the *biological productivity* of various natural landscapes or biogeocoenoses. Therefore this survey will concentrate on generalizing work that has already been accomplished, especially that of N. I. Bazilevich and L. Ye. Rodin.

This research is ultimately interested in the biological cycle of chemical elements in main types of vegetation, in particular, the primary production (phytomass) in natural landscapes (biogeocoenoses) and its chemical composition. Consequently, these studies do not cover the internal cycle of materials in natural landscapes (biogeocoenoses) taken as a whole. Nevertheless, studying the first, initial "leg" of that cycle (primary production) is essential for all aspects of landscape studies and biogeocoenology.

In their calculations of primary biological productivity the researchers used the following indicators: the total amount of phytomass in biogeocoenoses; its annual increase, annual litter, total increase, and accumulation of dead organic substance in the forest litter. The total phytomass was classified into the green part, perennial surface, and roots; the fraction of each part in the total phytomass was calculated, as were the fraction of litter in the phytomass, and the ratio of the litter to the green leaf fall-out. With the aid of this system of indicators it was possible to reach very interesting and important conclusions used in considering major scientific problems even on a global scale.

The study of the *geochemical conjugation* of various natural landscapes, or biogeocoenoses, is a concept to be considered in terms of characteristics which are also used in the description of the internal cycle of materials. As stated above the general concept of geochemical conjugation of various natural landscapes was formulated long ago by Polynov. It is directly related to conventional ideas on the division of all natural landscapes into zonal flat interfluves (watersheds), intrazonal (slopes), and azonal (depressions). Also helpful is Polynov's concept of "geochemical landscapes" which is understood to be a series of geochemical landscape formations which change with relief elements from watersheds and slopes to depressions. Among these are eluvial or autonomous (watershed), transaccumulative (slope), super-aqueous accumulative (depression), and subaqueous (underwater) geochemical landscapes.

Perelman and Glazovskaya extended this approach to soil geochemistry. "The flow of material particles, atoms, and

their compounds links components of the landscape such as rocks, weathering products, waters, soils, vegetation, and near-surface atmosphere ... into one entity, wrote Glazovskaya in her article "Types of Soil Geochemical Conjugations", *Proceedings of Moscow University* (1969). "Soil is an especially important component of the landscape; a migrating flow of elements streams through it. It is therefore a materialization of the other components and of their geochemical links." This is precisely why studies of geochemical conjugations in natural landscapes paid particular attention to various specifics of the chemical composition of soils and zonal elements in the composition of vegetation. Special concepts and indicators for the characterization of the elements have been introduced—geochemical "barriers" (evaporating, restoring, crystallizing, biological, etc.) which facilitate retention and accumulation of materials; true and "false" geochemical anomalies; and geochemical landscape factors (eluvial-accumulative, absorption, water migration, and biogenic migration).

Research into the *energetic essence* of material cycle processes in natural landscapes was begun by Grigoryev and Budyko. They related the intensity of dynamic processes (in particular biological productivity) in natural landscapes to the amount of solar heat and atmospheric humidity (and their ratio). In their essay, "The Productivity and Cycle of Elements in Natural and Cultural Phytocoenoses" (1971), Bazilevich and Rodin calculated the average annual production of the assimilating part of the phytomass for various types of vegetation in the USSR. They obtained certain values (0.1 for deserts to 1.0-1.5 and 3.0-3.6 ton·hectare/year for steppes and forests), which were compared with the values of radiation balance and radiation dryness index computed according to Budyko. In this way they correlated the formation of primary biological production with the amount of radiation heat and atmospheric humidity. Budyko improved on these calculations in his book *Climate and Life* (1971). According to him, "the annual increase of organic material uses up to two per cent of the incoming photosynthetically active radiation". This value ranges from 0.1-0.2 in deserts to 1.0-1.2 per cent in steppes and forests.

Workers at the Kursk station of the Institute of Geography, USSR Academy of Sciences, have developed and applied

a more detailed and direct method for determining the efficiency of using radiation and humidity in the forest-steppe ecosystems in European USSR (A.M. Grin, Yu.L. Rauner, V.D. Utekhin, 1970). They obtained numerous important energy characteristics of the production process and found that with equal radiations and similar atmospheric humidifications, the structures of radiation heat and water balances differed in steppes, oak-tree forests, and cropland. Thus, the ratio of absorbed and incoming photosynthetically active radiation and of transpiration to precipitation increases in the cropland-steppe-forest series. The efficiency of using radiation in photosynthesis, and of transpiration, however, increases in the forest-steppe-cropland series. These findings led to the conclusion that "natural ecosystems (especially the forest) absorb incoming radiation and precipitation better than the agrobiocoenosis but use them less efficiently in photosynthesis and transpiration". This "Kursk-type" research which is now being carried out in various localities is very useful in devising methods for characterization of processes in natural landscapes.

Thus far three lines of research have been discussed where landscape science and biogeocoenology tend to merge in the USSR. It is important to emphasize that in all these cases this trend is felt in the research where the objective is either an in-depth analysis of earlier results (studies of primary productivity) or a more detailed search using the latest methods (such as research in geochemical conjugation and energy essence of processes in natural landscapes or biogeocoenoses). These trends are not accidental; rather, they are the logical result of a general consolidation or interaction between various branches of research (through synthesis) as the objectives of the science become increasingly more sophisticated.

In this context, studies of the *internal structure* of natural landscapes or biogeocoenoses in the framework of the functional approach are now of special importance. The relevance of this approach has been recently emphasized in the latest international project "Man and Biosphere" (MAB) and in the declaration of a general scientific approach to its development. This project emphasizes again that the core of the ecosystem is a mechanism capable of intercepting solar radiation energy, converting it into chemical energy through photosynthesis, and distributing that chemical energy so as to maintain its functional structure. Green vegetation is the

photosynthetic tool. The herbivora and predators facilitate distribution of energy and substance while destructors dispose of dead organic materials thus releasing the minerals contained in them for reuse by plants. The control mechanisms, often closely related to the variety of species (ecosystem), enable the ecosystems to maintain or recreate, if disturbed, their *functional structure*.

It cannot be overemphasised that to study the "core" of ecosystems is to identify and characterize their general functional structure which consists of three basic components – producers, consumers, and reducers. Determination of characteristic (dynamically balanced or climatic) relations between these components inherent in a particular type of natural ecosystems is necessary for the rational typology of the ecosystems. Identification of the disturbed interactions (by natural elements or anthropogenic factors) is needed for the restoration (on a natural or artificial level) of a dynamic equilibrium, i.e., to a certain degree, the stability of ecological systems.

While Soviet landscape science has, as has been noted, made significant achievements in the *typology* of natural landscapes, biogeocoenology has always regarded the study of the internal *structure* of biogeocoenoses as its primary task.

N. V. Dylis in a chapter titled, "The Structural Functional Organization of Biogeocoenotic Systems and Its Study", to be found in the 1973 edition of *The Program and Methods of Biogeocoenological Research* differentiates between three basic organizational aspects: *structural physical* which characterizes the spatial grouping and location of living and abiotic bodies (in a biogeocoenosis); *functional*, which represents their interaction and work; and *temporal*, which records the dynamics of addition and work. He notes that "all these aspects are organically interrelated and are seen in biogeocoenological systems as different facets of the same phenomenon".

In this "phenomenon" Soviet biogeocoenologists were primarily concerned with its component-wise structure, i.e., the composition of material bodies such as plants, animals, soils, waters, air masses, etc., which together make up biogeocoenoses. In the course of these studies, valuable concepts were formulated of "biogeocoenotic parcels" (Dylis, 1969) as elementary structural parts of horizontal cross-sections of biogeocoenoses (analogues of "landscape

tacies"), and "biogeocoenotic horizons" as elements of their vertical classification (Yu.P. Byallovich, 1960). Studies of component-wise structure have always been closely connected with functional analysis, above all with the study of trophic (feeding) links. T.A. Rabotnov (1969) was especially interested in this study and developed the concept of *consortia*, or unions of a population of different autotrophs with heterotrophs, or their analogues in biogeocoenoses. V.N. Beklemishev and L.G. Ramensky pioneered this field back in 1952.

Soviet science has thus accumulated an impressive body of knowledge on the functional structure of natural landscapes and biogeocoenoses. It was therefore reasonable that an essay on "The Material Cycle within Major Types of Natural Ecosystems of the USSR" which I and my colleagues, Yu.A. Isakov and D.V. Panfilov, wrote should be presented at a state-of-the-art conference in biogeocoenology (Leningrad, 1971). The conference also dealt with research conducted in biogeocoenological stations. This essay was published in *Transactions of the USSR Academy of Sciences, Geography Series*, No. 2, 1972. The essay and an article which followed it up described our use of a set of quantitative indicators to characterize the internal cycle of materials in various natural ecosystems and the basic features of its anthropogenic transformation.

In a general resolution of the conference our methods were referred to only in the broadest terms as a promising scientific approach. I am not aware of any other specific response to the article. This is especially regrettable since even while writing the article, it was clear that the proposed approach needed comprehensive critical reviewing, verification, and refinement. This was already obvious from our own evaluation of our proposals as a hypothesis or a working model.

Let us recall the essay and the article; the term "natural ecosystem" used there will be replaced by "geocobiota". The reasons for this replacement will be described below.

We proposed a system of characteristics (indicators) for the internal cycle of materials in various geocobiotas which aims to cover the cycle as fully as possible:

-the type of internal cycle which depends on the source and the nature of inflow; all geocobiotas were thus classified into autonomous (independent), transitory (dependent), and accumulating (subordinate);

•

– *the degree of closure or autonomy* (for autonomous or independent geocobiotas) which is dictated by the levels of using the materials;

– *the intensity or rate* of the material cycle (the ratio of the annual biological production to the total biomass and other indicators);

– *the general structure* of the material cycle which can be characterized in terms of *completeness* (use of the annual biomass increment for respiration of the entire biota); *balance* (the ratio of the primary and secondary biological production); and *residual productivity* (the ratio of the masses of living and dead organic materials).

By use of these indicators we arrived at certain conclusions:

1. A high degree of closure of the cycle or high sophistication of the functional structures are characteristic of most zonal natural geocobiotas in European USSR (especially for broad-leaved forests and grass steppes). A clearly imperfect cycle which loses much of its biogenic substances is characteristic of the tundra and dark coniferous taiga.

2. The intensity or rate of substance cycle is at its highest in broad-leaved forests and grass geocobiotas of semi-arid areas where a favourable combination of heat and humidity insures variety and high activity of vegetation (producers), animals (consumers), and bacteria (reducers). Therefore the synthesis of primary production, its transformation into secondary production, and final mineralization are rapid.

3. There is an essential difference between these two types of natural geocobiotas as far as the reserve of biogenic substances (i.e. the general structure of material cycle) is concerned. That reserve is small in broad-leaved forests (high level of completeness and degree of balance of the functional structure) and large in steppes (high level of residual productivity). This should be kept in mind when trying to make a geocobiota highly resistant to crises in the environment such as droughts during which production of the primary biomass is dramatically reduced resulting in a temporary disturbance of the entire system of dynamic balance in the existing geocobiotas.

These formulations rely on quantitative data reported in Soviet literature on the characteristics of main zonal geocobiotas, and on some qualitative material (for instance, soil types). Furthermore, certain assumptions and working

models were made (as have been previously stipulated). On the whole, and it is necessary to emphasise this, structural characteristics or indicators are based on a general synthesis of geographic (landscape science) and biological (biogeocoenotic) ideas on geocobiotas in Soviet science at large. These characteristics complete and refine general systematic projects findings based on vast descriptive data on the structures of zonal geocobiota types and make it possible to raise numerous questions concerning various geocobiotas, both theoretical (e.g., historical evolution) and practical, (e.g., stability maintenance).

Formulation and actual use of these indicators have been largely made possible by earlier proposals concerning functional characteristics such as identification of basic and functionally different geocobiota components (producers, consumers, and reducers) and their most important characteristics (stores of biomass, biological productivity, biological cycle of materials, etc.). We feel that many new proposals regarding various geocobiota types (for instance, transitory and accumulating) can be made from that research.

Making an exhaustive set of characteristics is, however, hindered by the shortage and incompleteness of raw data on different geocobiotas. These data are reasonably plentiful for the process of creating primary biomass, lacking on secondary biomass, and in very short supply on the consumption of primary biomass for the respiration of the entire biota in geocobiotas and on its transformation by heterotrophs. The scarce data must be supplemented with calculations on hypothetic assumptions. For these reasons observations and experimentations should be expanded.

In conclusion, a few words on terminology. We have seen that the introduction of a new term, "biogeocoenosis", to replace the customary term in Russian science, "natural landscape", was dictated by the desire to emphasize a new line of research and a new approach to natural landscapes. Today Soviet geographic and biological sciences are witnessing a broad synthesis of landscape science and biogeocoenology caused by the deepening and complexification of the tasks of studying common features and the use of the latest methods. Therefore, we feel it advisable to mark this important process by the introduction of a new and quite autonomous term intended to emphasize

•

the more modern understanding and interpretation of the terms "natural landscape" and "biogeocoenosis".

We propose to use the term "geoecobiota". The last syllable of the word "geoecobiota" denotes a mass (a system) of living organisms and the biogenic substance that they create. The middle syllable signifies a dynamic balance in the relationship of that mass (system) of living organisms and the biogenic substance with the (physical) surroundings. Finally, the first syllable emphasizes that the spatially limited mass (system) of living beings and biogenic substance within a certain geographical space are in dynamic balance with a certain physical environment. Within that space certain environmental parameters and functional relations of the biota with the environment are maintained. Outside that space this "geoecobiota" starts decomposing and a new one begins.

To summarize, "geoecobiota" rather than "natural landscape", "biogeocoenosis", "natural ecosystem" or the recently proposed "geosystem", "toposystem", etc. seems to be strictly logical and international.

## **DEVELOPMENT OF SCIENTIFIC FUNDAMENTALS FOR GEOSYSTEM MONITORING: MAJOR OBJECTIVE OF GEOGRAPHY**

The term "monitoring" has been extensively used in connection with the environment in scientific and popular literature and in various official documents.

This term was introduced in 1971 when a commission of the Scientific Committee on Problems of the Environment (SCOPE) under the International Council of Scientific Unions (ICSU) published a booklet in which an international project was proposed which was referred to as "global monitoring". The booklet indicated that the system denoted by that term would be engaged in three basic activities: the systematic observation of the state of the environment and determining its possible (especially, man-made) changes; the control of such changes; and steps to regulate (manage) the environment. "Global monitoring" or simply "monitoring" is understood to imply the first two activities (observation, forecasting and control), but in describing activities mentioned one should keep in mind the final goals of a rational regulation of the environment by the use of monitoring.

- The term "monitoring" was also applied to the environment in recommendations of the UN Stockholm Conference on the Environment in 1972 and later in the activities of the United Nations Environmental Program (UNEP) and in the UNESCO-sponsored "Man and Biosphere" (MAB) project. It is also used in documents of the World Meteorological Organisation (WMO). In almost every case global monitoring is meant, i.e., a system of

observing and recording the changes in the environment of the entire planet in the framework of international projects.

In the USSR too "monitoring" is widely understood. This is due mainly to the efforts of the specialists working at the State Hydrometeorological Service (now the State Committee for Hydrometeorology and Control of Natural Environment). Many collections of works under the common title *Problems in Ecological Monitoring and Ecosystem Modelling* were published (1978-1980). Yu. A. Izrael's book, *Ecology and Control of the Environmental State*, was published in 1979 and included a chapter on ecological monitoring. He defined this concept as follows: "Ecological monitoring is a comprehensive subsystem of biosphere monitoring. It includes observation, estimation, and forecasting of anthropogenic changes in the state of the abiotic component of the biosphere (including changes in the pollution level of natural environments), of the ecosystems' response to these changes, and of anthropogenic changes in ecosystems caused by pollutants, agricultural use of lands, timber cutting, urbanization, etc."

This definition is very broad in scope and leads to far reaching conclusions. This is evidenced by a classification of monitoring systems and subsystems given in Table 1. I have not the slightest doubt that many scientific and practical programs included in the systems have a direct bearing on objectives of today's geography.

For these reasons I have in recent years worked on monitoring the (natural) environment from a geographic point of view. In my first essay on the subject,<sup>1</sup> the multi-component aggregate of natural phenomena subject to various natural changes and various anthropogenic influences was regarded as the general subject of monitoring. Comprehensive observations on the state of this aggregate of phenomena is very involved and cannot be undertaken unless divided into more particular subtasks. This is done by identifying different steps (blocks) of the system as a whole without losing sight of the object of observation or its value in the entire environmental monitoring system.

Further, I suggested that the first step of environmental monitoring should be bioecological (or environmental health)

---

<sup>1</sup> I. G. Gerasimov, "Scientific Fundamentals of Today's Environmental Monitoring", *Transactions of the USSR Academy of Sciences, Geography Series*, 1975, No. 3 (in Russian).

Table 1

**Classification of Monitoring Systems (Subsystems)**  
(after Yu. A. Izrael, 1979)

Classification principle	Monitoring systems (subsystems), existing or under development
General purpose	Global monitoring (basic, regional and local levels), including background and paleomonitoring National monitoring (e.g. in the USSR a state-wide service for the observation and control of environmental pollution) Multinational, "international" monitoring (e.g. the transfer of pollutants across national borders).
Reaction of main biospheric components	Geophysical monitoring Biological monitoring Ecological monitoring (including the above)
Different environments	Monitoring of pollutants and changes in the atmosphere, hydrosphere, soil; biota pollutions Reading: monitoring of the atmosphere, the ocean, terrestrial surface (with rivers and lakes), and cryosphere
Factors and sources	Ingredient monitoring (e.g. of radioactive products, noise, etc.) Monitoring of pollution sources
Acuteness and global scale of the problem	Monitoring of the ocean Monitoring of the ozonosphere Genetic monitoring
Observation methods	Monitoring in terms of physical, chemical, and biological indicators Satellite monitoring (remote techniques)
Systems approach	Medico-biological (health) monitoring Ecological monitoring Climatic monitoring Reading: biological, geoeological, and biosphere monitoring

monitoring. Its principal element is the observation of the state of the environment insofar as it influences the health of individuals and the population. Such phenomena and processes and, consequently, their indicators can be most varied.

Indicators which are most "sophisticated" for widespread use in a bioecological monitoring system are those of air, water, and soil pollution, i.e., the so-called indicators or norms of the highest admissible concentration of certain substances that are introduced into the environment as fertilizers, pesticides, and society's wastes. These indicators obviously vary with the substances and the hazards introduced.

It would be, however, erroneous to confine the norms of bioecological (environmental health) monitoring to toxic chemical substances. Numerous physical phenomena such as noise, which causes psychogenic disturbances in man and animals; biological phenomena which cause allergic ailments, etc., should be included.

Bioecological (environmental health) monitoring is a long-recognized need. Various national agencies which perform this service have also long been in existence. What is needed now is not only to maintain and expand these agencies, but also to provide them with higher levels of science and technology, making the findings more informative and representative. We will later discuss the significant contribution that geography can make to this type of monitoring.

The second stage of monitoring should, in our opinion, be a geosystem or a natural-economic monitoring. This includes the observation of changes in those main geosystems (including natural ecosystems) which comprise the environment (agrosystems, the urban environment, the environment of industrial areas, etc.). Geosystem monitoring is an absolutely indispensable supplement of ecological monitoring for the following reasons:

- it identifies the origin and interrelationship of those environmental phenomena which act as indicators of ecological monitoring (such as pollutants);

- it enhances the findings of ecological monitoring in that it forecasts uncontrollable changes in the environment and phenomena which defile the human and biotic environment;

- it expands the boundaries of ecological monitoring by

incorporating into its scope the natural resources that are used in the economy.

To explain the first assertion let us recall that for correct ecological evaluation of indicators or norms of the highest admissible pollutant content, it is necessary to determine the self-purification capability of the environment. This capability is stipulated by trophic as well as other links between the components of natural ecosystems (producers, consumers, reducers), and the intensity and rate of the natural biological cycle. Therefore, by introducing self-purification indicators into the set of geosystem monitoring indicators we are able not only to keep track of an "overload" of pollutants in natural ecosystems but also to predict the highest admissible load of society's wastes that a geosystem can "absorb" by virtue of its natural "stability" or "resilience". Such indicators should obviously be determined from studies of trophic links and from the rate of the biological cycle in the most important types of natural and natural-economic geosystems.

To understand the second assertion one should recall the widely-held opinion of a natural ecological balance; if this is disturbed, nature is "pillaged". This word essentially denotes the complete destruction of a natural ecosystem where a radical change in the natural flow of energy and materials and any disturbance of their balance result in irreversible phenomena which lead to the destruction of the entire geosystem. Such are the cases of accelerated erosional soil and territory washing (which are caused by a disturbance in the natural water balance, deforestation or cultivation of an entire catchment area and hypertrophy of surface runoff; of secondary salination of soils and ground waters which occurs in a disturbed water balance of an irrigated field; of processes of eutrophication ("water bloom") when a water pool receives an excessive amount of "nutrients", etc.

Consequently, the most important control indicators of geosystem monitoring should include certain characteristics of natural and natural-economic systems, typical of both "balanced" and "pillaged" (disturbed) geosystems.

To clarify the third assertion, the detection of natural geosystem resources, let us recall that biological productivity is a major property of natural ecosystems. Therefore, in our view, geosystem (natural-economic) monitoring can and should include certain indicators of biological productivity both for natural ecosystems and for natural-economic geosystems (agrosystems, protection forests, fishing ponds,

etc.). A comparison of these indicators would determine the efficiency of using such natural resources as climatic, soil and water, biological in accurate quantitative terms.

There is an important difference in procedure between bioecological and geosystem monitoring. The former relies on a systematic observation and measurement of certain environmental parameters (geophysical, biochemical, and biological) of bioecological importance in a network of stations; it is largely local. The latter monitoring, which relies more on geophysical, geo- and biochemical and biological methods must use a system of key (testing) areas as well as ecological monitoring stations; it is thus largely regional. Such areas may be viewed as geosystem testing grounds and it is here that geosystem tests (indicators) should be developed for monitoring of the entire environment.

Though not necessarily very extensive, the network should be fairly representative; one testing ground in each natural zone or large natural-economic region would essentially do. The condition of the most important ecogeosystems should be observed and controlled (in a given zone or region). Three groups should definitely be included: natural geosystems found more or less in an undisturbed state; the main natural-economic geosystems (above all typical agricultural geosystems); and man-made geosystems of the "highest rank" (optimized or managed—such as urban, industrial, and recreational) which are contiguous or at some distance from each other, but in similar natural conditions. In the first group, observations should concentrate on trophic links (biological cycles) and their disturbances; in the second, on how extensive is the use of natural ecosystem resources for the benefit of mankind (above all for the production of biomass); and in the third, on the effectiveness of management methods in using natural conditions and resources for the preservation and improvement of the environment for the population. The most complicated and least workable options and optimal criteria are found in the third group. For this reason, modelling should probably be employed.

One should be aware of the fact that while the first stage of monitoring, bioecological (environmental health), enjoys complete public support and has already begun to be implemented, the second stage, geosystem (natural-economic) does not.

The third stage should be biospheric monitoring. This

should provide observations, controls, and the forecasting of possible changes on a global rather than a regional (geosystem) scale, i.e., should include the entire biosphere as man's environment and biospheric changes as a result of human activities. In this way biospheric monitoring completes bioecological and geosystem monitoring to form an integrated system of mapping—the entire environment (biosphere).

These stages are summarized in Table 2.

There is hardly any need in emphasizing that today's geographic science should play an essential role in developing scientific fundamentals and effective organization, especially in the second stage of geosystem (natural-economic) monitoring. There is still much to be done, but certain theoretical and organizational groundwork has already been laid and further constructive activity in this field is feasible.

We are unable in the confines of this article to survey the findings made by various Soviet scientific institutions on the structure of natural ecosystems or on ecosystem modelling. These findings are the theoretical foundation of monitoring and contributory to the ultimate goal of today's geographic science—the development of optimum natural-economic geosystems through the transformation of natural ones.

Table 2

### System of Ecological Surface Monitoring

	Biological (environmental health)	Stages of monitoring	
		Geosystem (natural-economic)	Biospheric (background)
Objects.	Near-surface atmosphere	Disappearing species of flora and fauna	Atmosphere (troposphere) and ozone screen
•	•		
	Surface and ground waters	Natural surface ecosystems, their soils and environment	Hydrosphere Vegetation and soil cover
	Soil layer.	Water bodies	Animal population
	Industrial and domestic wastes	Agrosystems	
	Heat radiation	Afforestation	•
	Radioactive radiation	•	

	Biological (environmental health)	Stages of monitoring	
		Geosystem (natural-economic)	Biospheric (background)
Indica- tors	Maximum allowable concentration of toxic substances	Vegetation and animal population	Radiation balances Atmosphere over-heating
	Physical and biological irritants (noises, allergens, etc.)	Micro- and mesoclimate of natural ecosystems, agro-systems, and afforestation	Gaseous composition of the atmosphere and dust pollution Pollution of rivers and water bodies
	Maximum heat and radioactivity	Water balances of lakes and catchment basins	Water basins and cycles of water in vast catchment areas and continents
		Soil regime	
		Functional structure of natural ecosystems and its disturbances	Global characteristics of soils, vegetation, and animal population
		Status and productivity of crops	Large scale cycles of CO <sub>2</sub> and O <sub>2</sub> due to photosynthesis and respiration of the biota and sea sedimentation accumulation
		State and productivity of forest plantations	Large-scale material cycles and other cycles
Services and bases	Hydrometeorological, water-economy, hygienic and epidemiological, etc.	Ecological research stations (geosystem testing grounds Agricultural stations and forestries Natural reserves Aerospace services	International biospheric stations

We may summarize as follows: the main objective of geosystem monitoring should be the observation and control of man-made geosystems. The knowledge gained by such monitoring would allow for, first of all, a general estimate of

the productivity of geosystems in comparison with that of natural ecosystems, thereby evaluating the economic effect obtained by anthropogenic restructuring of geosystems. These findings should then be used as the basis for research in the creation of optimally productive stable and active-reserve cultural natural-economic geosystems. So, the task of today's geography is thus not only to develop scientific foundations for geosystem monitoring, but also to further use its data for such constructive geographic studies as have just been mentioned.

I believe that a strong foundation for such research is already available, although it is more empirical than theoretical. A tremendous amount of agronomic and afforestation work has been primarily directed at improving the biological productivity of crops, cultivated meadows, and forests. In the creation of agricultural and forestry geosystems it is helpful to increase the productivity of natural grassland and forest ecosystems through the effective use of pastures and haylands, their chemicalization, improvement of grasses, rational timber cutting, reafforestation, etc. The theoretical analysis of this vast experience in terms of geosystem monitoring and its ultimate goals promise to be important and rewarding work. Experimental agricultural stations and forestries can and should be the core of a geosystem economy monitoring system.

Still, development of a full-fledged general theory for managing the anthropogenic transformation of natural ecosystems and the systematic design of "prosperous" geosystems will require considerable time. Therefore simplified and approximate methods should be developed for immediate use both in geosystem monitoring and in the constructive application of its findings, especially those from work done in geosystem testing grounds.

We feel that an article written in 1972 by myself, Yu. A. Isakov and D. V. Panfilov, "The Material Cycle within Major Types of Natural Ecosystems of the USSR" is beneficial. It has led to the concept of a functional structure of natural ecosystems and their anthropogenic transformation. Our proposals are represented in structural form in Fig. 1.

The reference model is a climax (balanced) natural ecosystem (1) whose characteristics are:

1. The total amount of mineral materials involved in the biological cycle (mobile biogens).

2. The total biological mass and the store of mineral materials in the natural ecosystem which is classified into (a) surface and (b) subterranean.

3. Primary biological product (annual).

4. Secondary biological product (annual).

5. Balance of biological products (1) expressed as the ratio of annual primary and secondary products.

6. Biological product formation rate (2), expressed as the ratio of primary annual product to the total ecosystem biomass.

7. Material cycle rate (3), expressed as the ratio of the total store of mineral materials in the biomass to the amount of biogens.

These characteristics are in obvious agreement with S.S. Schwartz's criteria for "optimality" of anthropogenic transformation. Thus the total biological mass and the rates of its formation and balance characterize the general level of productivity as well as its stability; the cycle rate designates the self-purification and reserve activity rates of "good" or "prosperous" geosystems, etc. Consequently, our set of real characteristics in a way specifies the theoretical formulations of S.S. Schwartz.

Arched arrows (8) show the direction of biogenic flows inside a geosystem. If these are accompanied with numerical data for various types of climax ecosystems, then a simplified numerical model of a reference natural ecosystem is obtained with which its anthropogenic versions can be compared. In derivative (natural-economic) geosystems, the human impact will obviously be felt as disturbances (deformations) of the above parameters of the reference ecosystem. The possible consequences are:

9. Significant disturbances of characteristics 5, 6, and 7.

10. Tangible removals from flows (reduction of 8).

11. General weakening of flows (reduction of 8).

12. Significant reduction of 1, 2, 3, and 4.

13. Significant increase of 1, 2, 3, and 4.

---

*Figure 1. Flowcharts of a Reference Natural Ecosystem and Its Anthropogenic Disturbances*

I. Balanced natural ecosystem (climax). II. Disturbed natural ecosystem (climax) in crop-raising context. III. Disturbed natural ecosystem (climax) in forestry context (without afforestation). IV. Disturbed natural ecosystem (climax) in pasture grazing context. 1. mobile biogens; 2. total biological mass and reserve of biogens there (a. surface, b. subterranean); 3. primary biological production (annual); 4. secondary biological production (annual); 5. balanced biological production; 6. rate of formation of biological production; 7. rate of material cycle; 8. biogenic material cycles; 9. disturbances; 10. removals; 11. additions; 12. reductions; 13. increases.

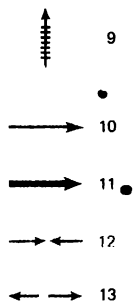
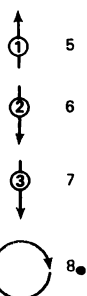
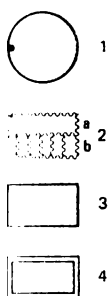
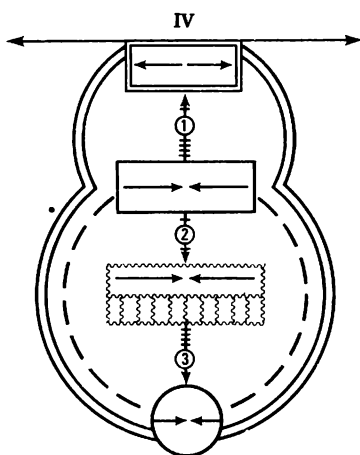
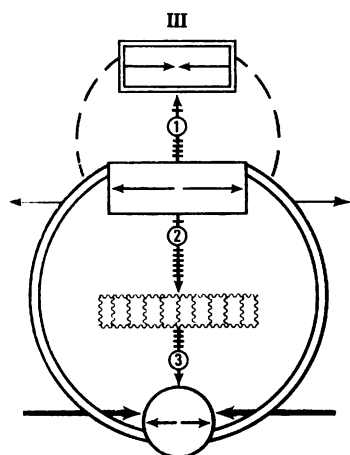
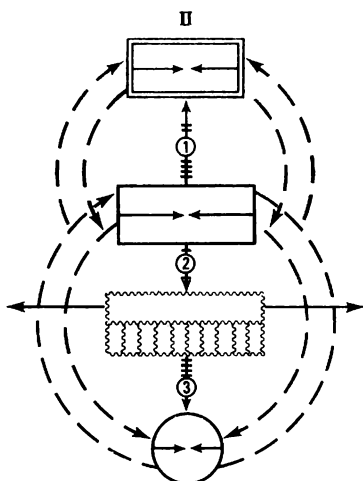
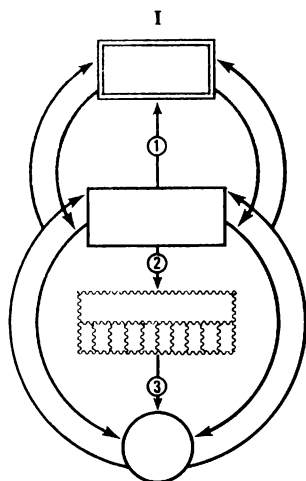


Figure 1 shows the chart of these disturbances for models of a forest geosystem (without afforestation) (II), for a geosystem used for cultivation of crops (III) and as pasture (IV).

Let us briefly consider these models.

In model II some of the biological mass (wood) has been taken from natural geosystems. In this way what is primarily disturbed (reduced) is the total amount of matter in the natural cycle. This results in a weakening of biogenic cycles which insure a natural annual level of primary and secondary biological production. Consequently, its balance and rate of formation are reduced and therefore disturbed. This immediately leads to disturbances which can and should be expressed in terms of the quantitative characteristics of the above functional indicators. Depending on the specific amounts of removal, the disturbance of ecological balance (and thus the changes of functional indicators) in a forest ecosystem may lead to complete destruction (or the formation of wastelands).

Model III depicts a disturbance of a natural reference ecosystem by agricultural activities where the entire surface biological mass is ploughed into the ground and, subsequently, a major portion of the primary annual biological production is removed. The former activity disturbs the rate (volume) of the biogenic cycle. This, however, is usually offset by fertilization. Thus the biogenic material cycle can be maintained and even amplified if the primary biological production (harvest) is to be increased. Significant annual removals of that production reduce the secondary biological productivity and weaken (or terminate) the return of materials into biogenic cycles. As a result, both the natural balance of biological production and the rate (volume) of forming (restoring) its total mass are disturbed. Disturbances in a natural ecosystem used for agricultural purposes vary with the amount of the residual surface biological production, the amounts of the annual removal of primary production, and artificial increase of biogenic materials.

Model IV shows disturbances of a natural ecosystem by pastoral animal husbandry. A certain amount of secondary biological production is removed from such ecosystems. Simultaneously, man attempts to expand the production, which increases the biogenic material cycle in certain parts (at the expense of others) and results in a decline (pastoral digression) of both primary and total biological production.

All these factors contribute to an ecological imbalance in natural ecosystems where animal husbandry is practised. This is expressed in terms of various quantitative structural and functional indicators.

We believe that this approach is both feasible and necessary. It would be especially useful in geosystem testing grounds in identifying to what degree a natural (reference) ecosystem under various economic uses is being transformed by man. It is also a useful approach in the further design of optimum natural-economic geosystems. Such a study would produce predictable results. From a standpoint of "good" or "bad", the various consequences of such a transformation of natural-economic ecosystems would have different values. If, however, only the most productive and stable active-reserve geosystems are selected, then the geosystem approach should be supplemented with a techno-economic evaluation of those activities of man which yield the optimum (maximum) result. Such evaluation would, however, be outside the scope of geosystem monitoring methods. Nevertheless, the effective techno-economic management of an anthropogenic transformation of natural ecosystems and the creation of various optimum-production geosystems needs such evaluation.

**A FACILITY FOR EXPERIMENTAL FIELD STUDIES  
OF NATURAL AND ANTHROPOGENIC GEOSYSTEMS  
OF THE CENTRAL PART OF THE RUSSIAN  
PLAIN'S FOREST-STEPPE (ANALYTICAL DESCRIPTION,  
PROGRAM, INITIAL FINDINGS)<sup>1</sup>**

**(written jointly with A. M. Grin)**

Today's constructive geography, whose principles were formulated in the 1960s (Gerasimov, 1960, 1966), regards as one of its tasks the identification of principles governing the anthropogenic transformation of natural ecosystems and evaluating the effectiveness in anthropogenic geosystems of the use of the natural environment's potential resources. The further elaboration of such a class of problems cannot rest exclusively on traditional methods of study based on the findings of expeditions. It is necessary to organize complex field stations engaged in the study of the structures and processes that characterize the functioning of natural and anthropogenic geosystems, in identifying direct and feedback relations among system components and evaluating corresponding balances. The first such field station was established nearly twenty years ago by the USSR Academy of Sciences' Institute of Geography in a forest-steppe zone, at the geometric centre of the Soviet Union's European territory, approximately fifteen kilometers to the south of the city of Kursk. This is a zone in which the ratio of solar heat to atmospheric moisture is the most favourable one for the entire Russian Plain. Its hydrothermic regime is characterized by a radiation index of dryness (Budyko, 1956) close to unity; the yearly radiation balance is  $36\text{--}40 \text{ kcal/cm}^2$ , and there are approximately 650 mm per year of precipitation. The winter is usually moderately rigorous with a stable snow

---

<sup>1</sup> *Transactions of the USSR Academy of Sciences. Geography Series*, 1976, No. 1 (in Russian).

cover, while the summer is warm and moderately humid with infrequent droughts. The land surface of the territory being studied is a relatively flat, rolling lowland, denuded through erosion, broken up by gullies, composed of strata of sedimentary deposits, and overlaid with a mantle of loess-like covering clay. The absolute measures of watersheds are approximately 230-250 meters above sea level, while characteristic depths of gullies are 25-30 meters. The natural plant cover is a steppe covered with a variety of grasses (*Stipa pennata* L., *Zerna inermis* Lindm., *Stipa pennata* L., *Salvia pratensis* L.) and oak wood (*Quercus robur* L., *Aegopodium podagraria* L., *Q. robur* L., *Brachypodium pinnatum* (L) P.B.). Its soils are typical highly fertile chernozems. There are also leached podzolized and carbonate chernozems and occasionally soils, of the grass-chernozem and grey loess-type (*Landscape Geophysics*, 1967).

The central forest-steppe is a zone of developed agricultural activities, and one of Russia's traditional granaries. A large part is occupied by anthropogenic (agricultural) geosystems. Seventy per cent of the land is ploughed, while forest covers extend to less than 10 per cent of the area. In the autumn, winter, and spring nearly 70 per cent of the cultivated land is in fact ploughed, and approximately 25 per cent is occupied by winter crops. In the summer nearly half of the land under cultivation is occupied by grains, primarily wheat, 10-15 per cent by technical crops (especially sugar beets), 30-35 per cent by fodder crops (including corn) and fallow land, and 5 per cent by potatoes.

The principal objects of studies in the Kursk Experimental Field Station of the USSR Academy of Sciences' Institute of Geography are virgin steppe lands and natural oak forests of the Central-Chernozem Reservation, together with the adjoining highly productive fields of the Kursk State Agricultural Experimental Station. More recently they have come to include parts of Kursk that differ in terms of their forms of urbanization. The presence of such an assortment of objects (territories influenced by the mineral production activities of the Kursk Magnetic Anomaly will soon be added) with natural conditions that are practically identical, permits comparative analysis of the parameters of natural geosystems and of various types of anthropogenic modifications.

The research program of the Kursk Experimental Field Station has greatly evolved in the course of its implementation. Initially it concerned the preparation of an

inventory of natural conditions and resources. A second stage was concerned with evaluations of changes in natural geosystems under the influence of human activities (particularly agricultural activities) in order to estimate the effectiveness of natural resource utilization as natural geosystems are transformed into anthropogenic geosystems (natural-technological). Today this research concerns studies of the structure and processes that characterize the functioning of natural and anthropogenic geosystems with a view to constructing corresponding models that will make it possible to trace, control and forecast their state and development, govern its intensity and perhaps even its course.

In order to obtain the needed information complex field experiments are carried out (as well as some laboratory experiments) in which all major divisions of the USSR Academy of Sciences' Institute of Geography participate. The methods employed include both traditional methods such as comparative geographic studies, the methods of natural history, and cartographic methods, and also more recent ones (biogeophysical and biogeochemical methods) and very recent ones such as the measuring of distance with the help of aerophotography and space photography techniques).

Primary observations and measurements activities include the following major studies.

1. Studies of heat balance—including the measurement of flows of the sun's radiant energy, Earth and atmospheric radiation, of meteorological elements (temperature, air humidity, wind velocity) at various levels within the plant cover and above it, as well as measurements of soil temperature and of the plant mass. These data make possible calculations of vertical flows of heat and humidity within the plant cover and in the soil.

2. Water balance studies, including measurements of liquid sediments and their interception by the plant cover; the height of the snow cover, its density and the reserves of water that it carries; hydrometeorological factors influencing the development of incline runoff, its volume and intensity; evaporation, and its components (total, physical, transpiration); the redistribution of the soil's reserves of humidity over time in terms of types and rates of change, as well as the magnitude of both solid and dissolved substances carried by incline runoff, atmospheric precipitation, and lysimetric waters.

3. Phytometric studies, including measurements of the total biomass of plants and of its various fractions.

4. Zoometric studies, including quantitative estimates of the composition and rates of change of animal populations, of their influence on the primary production of the plant cover, and rates of change of microfauna at various levels of mineral nutrition.

5. Soil-geochemical studies, including quantitative estimates of geochemical parameters of the material cycle in the soil, in plants, in surface and sub-surface waters, and also some other parameters (*Biogeographic and Landscape Studies of Forest-Steppes*, 1972).

The research activities defined by the joint Soviet-American program for studying natural conditions and resources with the help of space technology, in which experimental objects of the Kursk Experimental Field Station are used as test grounds, have made it necessary to establish a special complex for surface observations as well as observations from various heights. They include: establishing the spectral characteristics of the natural and cultivated plant cover and soils, with due consideration of differences in their lighting conditions, development phases, humidity, and other external and internal factors; the photographing of research objects in various zones of the visible and infra-red part of the spectrum; the measurement of radiation temperatures, intensity of light, total albedo, and its narrow part in the zone of chlorophyll absorption ( $\lambda - 0.640$  nm); and establishing the magnitudes of soil and plant moisture, as well as the weight of that part of the biomass that is found above the Earth's surface. All these observations are being made in conjunction with flights of specialized aircraft, satellites, manned space ships, and orbital stations from which a remote sensing of the Earth's surface was carried out.

The results of those studies were analysed and published in a number of monographs and specialized collections and in numerous periodicals.

In particular the findings of the inventory of natural conditions on the territory of the Kursk Experimental Field Station that was carried out at the very beginning with the help of specialized large-scale landscape-typological mapping were presented in a study by D.L. Armand, A.V. Drozdov and L.S. Filippovich (1972). Subsequently emphasis was placed on studies of the specific features that characterized

the exchange of matter and energy in basic geosystems and on developing methods for describing them with the help of balance indicators (Drozdov, 1974, 1975).

An example that illustrates the possibilities and advantages of a systematization of natural complexes in terms of characteristics of their matter and energy exchange processes is provided in Table 3. All magnitudes relate to the middle of the vegetation period.

Table 3

**Indicators of the Composition of the Heat Balance  
and of the Phytomass of Natural Grass-Steppe Complexes  
of the Kursk Experimental Field Station**

Composition indicators		Natural complexes			
		Water-shed	Inclines of gullies		Bottom of gullies
			Facing North	Facing South	
R% of max.		89	62	100	94
Of heat balance	$\frac{LE}{R}$	0.47	0.70	0.48	0.76
P% of max.		79	67	76	100
Of phytomass	$\frac{G}{P}$	0.07	0.12	0.08	0.13

*Notation:* R – net radiation balance; LE – expenditures of heat on evaporation; P – total phytomass; G – green (assimilating) parts of the phytomass

Table 3 shows that there is a relatively clear correspondence between indicators of the structure of balances of heat and of moisture and the structure of the phytomass. This reflects specific features of the functioning of the geosystems being studied. Let us note that these distinctions are not evident from an examination of their physiognomic characteristics (component composition) (Drozdov, 1974).

Studies of the biomasses of major natural geosystems have made it possible to use the coefficients proposed by I. P. Gerasimov *et.al.* (1972) to compare general reserves, structures, rates of change and velocity of circulation of organic substances. The higher productivity of steppes by comparison with forests became apparent, especially in terms of general reserves of phytomass, as did the enormous difference (by one order of magnitude) of corresponding ratios of sub-surface phytomass to phytomass above the ground (Table 4).

**Selected Characteristics of the Circulation  
of Organic Substances within Grass-Steppe Geosystems  
at the Kursk Experimental Field Station  
(Calculated by A. V. Drozdov and R. I. Zlotin)**

Geosystems	Oak woods			Virgin steppes		(to be cut)
	Ws	Gn	Gs	Ws	Gn	Gs
Reserves of live phytomass (c/ha)	1,514	1,569	1,413	334	308	304
Ratio of yearly output to reserve (%)	8.0	7.6	8.5	42.5	45.8	43.0
Ratio of phytomass above ground to sub-surface phytomass	3.0	3.8	2.5	0.10	0.14	0.12
Ratio of green fraction to output (%)	45.0	32.5	38.0	28.9	36.2	34.4
Litter (in forests only) (c/ha)	73	65	66	—	—	—
Ratio of production to litter	1.7	1.8	1.8	—	—	—

*Notation:* Ws—watershed; Gn—gully incline facing North; Gs—gully incline facing South

These characteristics confirm the point that there are two fundamentally different ways to create reserves of primary biomass needed to overcome the ecological crises that are experienced by natural forest (wood) ecosystems and natural steppe (root mass) ecosystems in moderate zones (Gerasimov *et.al.*, 1972).

Studies of heat balance relations have established the existence of important differences in the radiation and heat balances of major geosystems of the central forest-steppes (Ananieva, 1967; Rauner, 1972; Rauner, Ananiev, Samarina, 1975; *Studies of the Genesis of Climate. The Heat and Radiation Balance...*, 1965; and others). An analysis of Figure 2 shows that the radiation balance of oak woods at the Earth's surface ( $R_{for}$ ) is substantially higher than that of grass steppes ( $R_{st}$ ) and that of grain cultures ( $R_{field \text{ of barley}}$ ). This is explained by differences in the coefficients of reflection of incoming radiations: the albedo of a forest is 14-17 per cent, that of a grass land is 20-24 per cent, while that of a grain field is 22-25 per cent. In this way the energy potentials of forest geosystems emerge as being greatest by

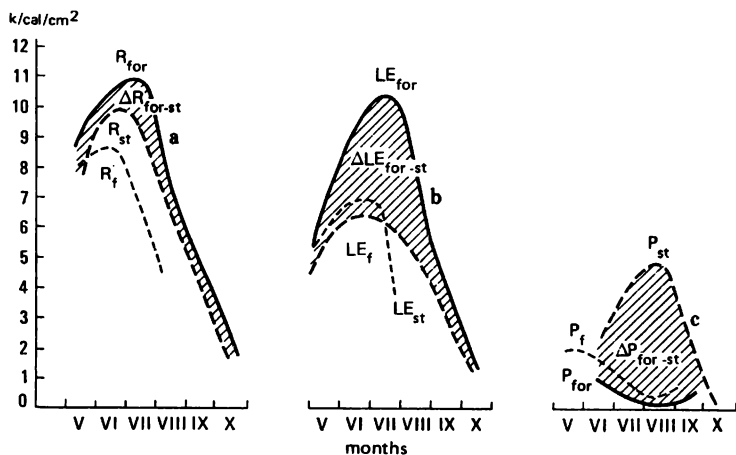


Figure 2. Components of Heat Balance of Major Geosystems of the Central Forest-Steppe (according to L. M. Ananieva)

R - radiation balance (for - forest, st - steppe, f - fields); LE - heat expenditure for evaporation (for - forest, st - steppe, f - fields); P - heat expenditure;  $\Delta$  - difference between heat balance components in forest and steppe.

comparison with other geosystems of the central grass steppes:  $R_{\text{steppes}}$  equals approximately  $0.85 R_{\text{forests}}$ ;  $R_{\text{field}}$  equals approximately  $0.8 R_{\text{forests}}$  (see Figure 2a). The major type of heat expenditure in the heat balance of all geosystems relates to aggregate evaporation ( $LE_{\text{for}}$ ;  $LE_{\text{st}}$ ;  $LE_{\text{f}}$ ); their order of importance, moreover, is forest-steppe-field ( $LE_{\text{for}} > LE_{\text{st}} > LE_{\text{f}}$ ) (see Figure 2b).

In mid-summer and under conditions of sufficient humidity heat expenditures on aggregate evaporation within the entire active layer of forest-steppes (medium-sized areas of broad-leaved forests) approach the corresponding magnitude of the radiation balance. As a result only a negligible part of the radiant energy is expended on heating the surface layer of air of forest geosystems. This is why the turbulent heat exchange between forests and the atmosphere ( $P_{\text{for}}$ ) is smallest in such regions (see Figure 2c); in fact both steppe geosystems and agricultural crops are marked by relatively high values of turbulent heat exchange.

A low heat exchange produces stable temperature stratifications over forests as well as "oasis effects". The resulting additional inflow of heat towards forest areas and adjoining territories creates conditions in which heat

expenditures on aggregate evaporation may exceed the value of the radiation balance. This expresses a certain "aggressiveness" of forested areas in forest-steppe regions.

A series of publications has been devoted to the water cycle in natural geosystems and to changes in its composition as a result of man's impact (Grin, 1965; *The USSR's Water Balance and Its Transformation*, 1969; *Methods for Studying the Water Balance of Territories and for Mapping Its Elements*, 1973; *The Water Balance of the Principal Ecosystems of the Central Forest-Steppe*, 1974). In the course of prolonged evolution conditions have developed in natural ecosystems that produce a maximal "assimilation" of precipitation and of their subsequent transformation into aggregate evaporation—a process that provides, through transpiration, the greatest possible increment in biomass. Moreover, in steppe and forest geosystems that are completely untouched by human activity, the water cycle is fully balanced since nearly the entire incoming moisture is evaporated. But even such modest economic activity as in mowing of grass or grazing cattle (in areas of the Central-Chernozem Reservation and for very light loads on grazing areas) produce perceptible increases in incline runoff and an unbalancing of the water cycle. The average magnitude of yearly differences in balances then amounts to as much as 10 per cent of precipitation (Table 5). In anthropogenic—field (ploughed land) geosystems changes in the composition of the water cycle are already quite pronounced, particularly visible during the spring thaw, when the high

Table 5

**Average Yearly Values of Water Cycle Elements  
in Natural Geosystems  
(based on observations of Kursk Experimental Field Station 1963-1973)**

Geosystems	Precipitation, P, mm	Aggregate evaporation, E		Incline runoff, S		Accumulated moisture in the soil, $\Delta W$	
		mm	"	mm	"	mm	"
Virgin uncut steppe land	537	518	97	13	2	6	1
Virgin steppe land, subject to cutting	513	434	84	50	10	29	6
Under grazing	517	450	88	44	8	23	4
Oak forest	552	546	99	3	0.5	3	0.5

infiltration capacity of typical thick layers of black earth during warm seasons causes the soil cover of any geosystem to nearly fully absorb precipitation. In the spring, depending on the nature of the surface of field geosystems, the incline runoff may range from an average of 27 per cent of the water contained in the snow on ploughed land to 70 per cent for winter crops (Table 6). It is difficult to construct a water balance for the entire year in the case of field geosystems, for the sequence in which the soil is worked does not lend itself to systemization.

Table 6

**Values of Water Cycle Elements on Ploughed Land during  
the Spring Runoff  
(for years of parallel observations in Kursk  
Experimental Field Station between 1962 and 1970)**

Type of land	Years of observation	Water content of snow, P, mm	Incline runoff, S, mm	$K = \frac{S}{P}$
Autumn ploughing	1962, 1963, 1965	101	34	0.34
Grain crops stubble	1966, 1970	129	80	0.62
Autumn ploughing	1962, 1964, 1965	105	28	0.27
Areas under winter crops	1967, 1968, 1969	124	87	0.70
Grain crops stubble	1962, 1965, 1967	122	71	0.58
Areas under winter crops	1968, 1969	119	83	0.70

We have already noted that during the warm season nearly all precipitation is expended on evaporation. There do remain differences, however, in the composition of evaporation for different geosystems. In particular, while in the case of uncut virgin land nearly 50 per cent of the moisture that evaporates during the period is used in transpiration only 35 per cent of the moisture of field geosystems is used productively (Table 7). Such a substantial difference is explained above all by the short vegetation period of cultivated plants and by very large losses of moisture, on ploughed black surface fields during two relatively prolonged periods, namely, from the end of the thaw to germination and from harvesting to snowfall.

Observations of rates of change in the moisture of soil layers over many years for all major geosystems and to a depth of 3-5 meters have made it possible to conclude that

**Composition of Evaporation Processes from Steppes  
and Fields (based on observations  
of Kursk Experimental Field Station)**

Geosystems	Years of observation	Aggregate evapo- ration, E, mm	Transpiration, T, mm	Non-productive evaporation, N, mm	T E %
Virgin steppe land, uncut	1967-1970	362	170	192	47
Virgin steppe land, subject to cutting	1963-1966	362	148	214	41
Barley field	1968-1970	450	158	292	35

a full penetration of moisture into the soil in the central forest-steppe region occurs quite infrequently. It was observed, moreover, only in forests (twice during 15 years) and on uncut virgin land (once). In all other geosystems the soil moisture of that layer never exceeded the lowest value of field moisture capacity. At the same time in shallow steppe depressions talwegs and other markedly depressed areas towards which there is an inflow of water from adjacent territories, one observes a complete penetration of moisture nearly every year. This provides a convincing confirmation of the hypothesis that in forest-steppe regions ground waters are fed from depressions (Grin, Evlakhina and Kuk, 1975).

Geobotanical (phytometric) studies relating in the first place to analysis of the composition of the steppe's plant cover and the biological production of its various parts and also of properties and factors determining the effectiveness with which plants utilize the environment's resources have made it possible to arrive at some understanding of the adaptive structure and edification structure of the geosystem's plant cover and also concerning methods for expressing rates of change of plants in quantitative terms. The edification structure of the geosystem's plant cover refers to the extent to which it is adapted to the absorption of the environment's resources, while its adaptive structure refers to their assimilation (Utekhin, 1973).

The findings of soil geochemical studies (that were carried out at the Kursk Experimental Field Station not only by staff members of the USSR Academy of Sciences' Institute of Geography but to a substantial extent by research staff

members from the V.V. Dokuchaev Soil Institute) are analyzed in the monographs of E.A. Afanasieva, *Chernozems of the Central Russian Plateau* (1966); of T. P. Kokovina, *The Water Regime of Fertile Chernozem Soils and Water Supply of Their Crops and Cereals* (1974); and in numerous articles published in journals and specialized collections. They contain detailed descriptions of various properties of the most fertile soils in the USSR and of fertile chernozems, as well as analyses of parameters of their water and thermal regimes. They also examine factors that determine their specific features. In recent years much emphasis has been given to the study of biogeochemic cycles in natural and anthropogenic geosystems, and to qualitative estimates of their parameters, including magnitudes of transfers of solid and dissolved substances at all stages of the water cycle.

The principal findings of zoogeographic studies were presented in a monograph by R. I. Zlotin and K. S. Khodasheva (1974). It contains an analysis of the effects of direct and indirect participation of major functional groups of heterotrophs in autotrophic biotic circulation cycles and in processes of destruction of organic matter. Original quantitative data are presented that characterize the highly significant role of indirect influences of animals on processes of biological circulation that operate through changes in the water, heat, gas and biochemical processes of ecosystems.

An analysis of comprehensive observations in major geosystems of the central forest-steppe region has made it possible to arrive at some initial conclusions concerning the effectiveness with which they use resources of heat and moisture in producing biomass (Grin, Rauner, Utekhin, 1970). The data that have been obtained indicate that within the forest-steppe-field sequence forest geosystems absorb resources of heat and moisture most intensively but utilize them least effectively in producing green biomass, while field geosystems (barley fields) on the other hand are marked by low absorption of environmental resources (losses are high) but utilize heat and moisture resources more effectively than do natural geosystems in forming biomass above the Earth's surface (Table 8). This provides a preliminary but nevertheless quantified explanation for a number of empirical hypotheses and practical recommendations. These include the causes of the displacement of steppes by forests in conditions of the central forest-steppe region; and ways to further improve field geosystems so as to obtain larger harvests with

Table 8

**Indicators of the Effectiveness of Use of Moisture and Radiation  
in Major Forest-Steppe Ecosystems (approximate values)**

Indicators	Steppe	Forest	Field (barley)	Indicators	Steppe	Forest	Field (barley)
$F_{inc}$ , cal/cm <sup>2</sup> /year	$4.5 \cdot 10^4$	$4.5 \cdot 10^4$	$4.5 \cdot 10^4$	$\eta_F$ , %	2.9	2.7	4.0
$F_{abs}$ , cal/cm <sup>2</sup> /year	$1.8 \cdot 10^4$	$2.4 \cdot 10^4$	$1.1 \cdot 10^4$	$\rho_F$ , %	40	53	24
P, mm	680	680	680	$e_F$ , %	1.2	1.4	1.0
I, mm	180	610	160	$\bar{k}_T$ , g/g	138	380	145
$B_{acc}$ , g/cm <sup>2</sup> /year	$13 \cdot 10^{-2}$	$16 \cdot 10^{-2}$	$11 \cdot 10^{-2}$	$\rho_W$ , %	27	90	24
$cB_{acc}$ , cal/cm <sup>2</sup> /year	$5.2 \cdot 10^2$	$6.4 \cdot 10^2$	$4.4 \cdot 10^2$	$K_T$ , g/g	520	425	620

*Note:* here  $\eta_F$ —is the efficiency coefficient in using photosynthetically active radiation (FAR) in forming biological output by plant components or else the ecosystems phytobiota (the photosynthetic efficiency coefficient of phytobiota);  $\rho_F$ —is the share of incoming FAR that is absorbed by the phytobiota ("utilization coefficient" of the FAR);  $e_F$ —is the efficiency coefficient in using the incoming FAR (the photosynthetic efficiency coefficient of ecosystems);  $K_T$ —is the expenditure of moisture per unit of the phytobiota's output (the phytobiota's transpiration coefficient);  $\rho_W$ —is the proportion of "absorbed" to "incoming" moisture, i.e. the expenditure on transpiration (T) from precipitation (P) ("the moisture utilization coefficient");  $\bar{k}_T$ —is the expenditure of moisture per unit output of plant mass (the ecosystem's transpiration coefficient);  $F_{abs}$ —is the FAR absorbed by the plant cover during the vegetation period;  $F_{inc}$ —is the FAR arriving into the ecosystem during one year;  $B_{acc}$ —is the plant's net biological production (after subtracting subsequent defoliation), their so-called absolutely pure production;  $c \approx 4,000$  cal/g— is the energy equivalent of plants mass.

$$\eta_F = \frac{cB_{acc}}{F_{abs}}$$

$$\rho_F = \frac{F_{abs}}{F_{air}}$$

$$e_F = \frac{cB_{acc}}{F_{inc}} = \eta_F \cdot \rho_F$$

$$k_T = \frac{T}{B_{acc}}$$

$$\rho_W = \frac{T}{P}$$

$$K_T = \frac{P}{B_{acc}} = \frac{k_T}{\rho_W}$$

a smaller volume of snow and incline runoff from fields, lengthen the vegetation period through the sowing of several crops on the same field during each season and the

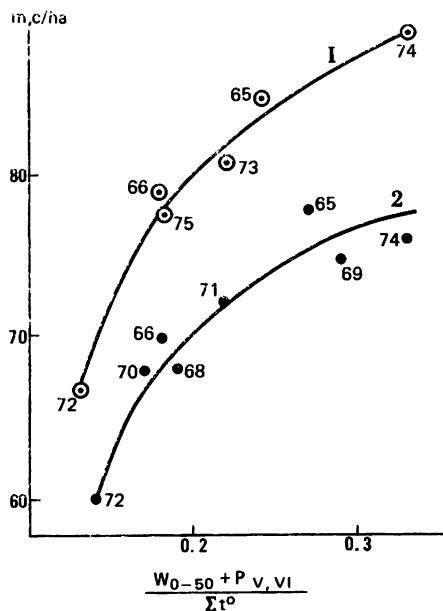


Figure 3. Biological Productivity of an Anthropogenic Geosystem (Barley Field) as a Function of Heat, Moisture, and Mineral Resources (as observed at the Kursk Experimental Field Station by A. M. Grin and V. A. Tiuleneva)

1 unfertilized field:  
 2 unfertilized field =  $\frac{W_0-50 + P_{V, VI}}{\Sigma t_j} = \text{CHI}$  (see explanation in the text).

understanding of active measures against weeds that usually occupy the same ecological niche as do cultivated crops.

Experiments seeking to obtain high and extremely high grain harvests conducted by the Kursk Experimental Field Station have established a relatively close dependence of the biological productivity of field geosystems (barley fields) on heat, moisture and mineral resources (Grin, Tiuleneva, 1975). Against the background of the high natural fertility of the soils an improvement in relations of supply of heat and moisture an increase in the value of a comprehensive hydro-meteorological indicator (CHI) from 0.1 to 0.2 led to an increases of 13 c/ha (centners, i.e. 100 kilograms, per hectare) in biomass productivity, while the addition of high doses of

mineral fertilizers further increased that value to 17 c/ha.<sup>1</sup> Improvements in germination conditions moreover, produce an increase in the effectiveness of the utilization of mineral resources. In particular, with CHI = 0.2 the productivity of a "fertilized" field exceeds by 9 c/ha that of one which is "unfertilized", while for values of CHI = 0.3 it is higher by 13 c/ha (Figure 3).

A synthesis of the findings obtained at the Kursk Experimental Field Station has made it possible to initiate activities in modelling both individual processes and the overall mechanism governing the functioning of basic geosystems in the central forest-steppe region. Flow models as well as block models of major forest-steppe geosystems have been constructed (D. Armand, Preobrazhenski, A. Armand, 1969) and of the moisture cycle within them (Grin, 1973).

Models based on empirical relationships represent interactions among such geosystem components as biological productivity and heat and moisture resources (Grin, Savelieva, 1971; Grin, Savelieva, Chernyshev, 1972), also mineral inputs (Grin, Tiuleneva, 1975). The infiltration capacity of soils and the magnitude of incline runoff have also been modelled (Grin, 1971). An attempt had been made to model mathematically the interaction of the environment's abiotic components (flows of radiation and of water) with parameters of the productive processes in terms of indicators of the effectiveness of photosynthesis and of soil cover composition. As a working hypothesis it was assumed that there exists some harmonious combination of materials and energy resources that will provide for an optimal primary ecosystem productivity (Grinberg, Utekhin, 1974).

Further research activities at the Kursk Experimental Field Station call for both a deepening and a widening of geosystem studies in order to develop more effective methods for constructing such models as well as a further extension of studies of natural conditions and resources through aerial

<sup>1</sup> The indicator  $CHI = \frac{W_{0.50} + P_{V,VI}}{\sum t_5^0}$ , where  $W_{0.50}$  represents moisture reserves in a 50 cm layer of soil at the beginning of the vegetation period;  $P_{V,VI}$  represents precipitation during May and June (the months of active vegetation); and  $\sum t_5^0$  represents the sum of "active" average daily temperatures (greater than 5°C.) during these months.

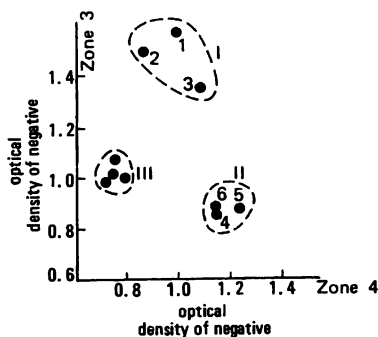


Figure 4

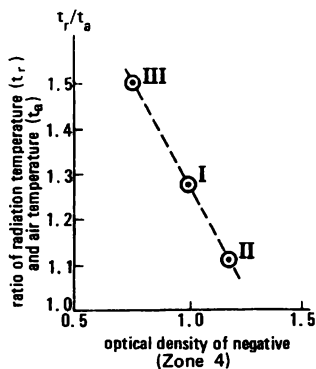


Figure 5

*Fig. 4. Identification of Agricultural Geosystems on the Basis of Multi-Zonal Aerial Photograph Data (Kursk test sector, end of July, according to Yu. N. Kulikov)*

I-ripening grain crops; 1-barley (wax ripeness); 2-winter wheat (wax ripeness); 3-spring wheat (milk-wax ripeness); II-actively growing crops; 4-millet (from shrub formation to ear formation); 5-sugar beet (the closing of adjacent rows); 6-corn (removal); III-black unplanted soil (dry bare soil-*chernozem*); zone 3-range-0.68-0.72 micra; maximum 0.69 micra; zone 4-range-0.75-0.86 micra; maximum-0.81 micra.

*Fig. 5. Relation of Radiation Overheating (Ground Level Estimates to Optical Density of Negatives (According to Aerial Photograph) in the Proximate IR-zone for Various Agricultural Geosystems (based on data from a synchronized experiment at the Kursk test sector, July 1974, according to Yu. N. Kulikov). Average values for:*

I-ripening grain crops; II-actively growing crops; III- bare black soil.

photography and remote sensing. These studies have already yielded some results.

In particular data produced by multi-zonal aerial photography in 1974 of the territory assigned to the Kursk Experimental Field Station permit a comparative analysis of individual zones that identifies various types of anthropogenic systems with some confidence (Fig. 4). A relation has been found between the magnitude of radiation overheating, as an indicator of long-wave radiation, and the spectral brightness of photographic representations of agricultural geosystems in the proximate IR (infrared) zone. This makes it possible to hope that an effective decoding attribute will be found (Fig. 5).

At a later point it is expected that the Kursk Experimental Field Station and the Kursk Aerospace Test Centre will serve as one of the USSR's major "biospheric stations

(reservations)" that are being established to serve as an upper level component of a global monitoring system whose purpose is to observe, control, forecast and regulate the state of the environment (Gerasimov, 1975).

## **Bibliography** (in Russian)

- Ananieva, L. M., "Heat Balance of Natural Grasses of the Forest-Steppe", *Transactions of the USSR Academy of Sciences, Geography Series*, 1967, No. 1.
- Afanasieva, E. A., *Chernozems of the Central Russian Plateau*, Nauka Publishers, Moscow, 1966.
- Armand, D. L., Preobrazhensky, V. S., Armand, A. D., "Natural Complexes and Modern Methods for Studying Them", *Transactions of the USSR Academy of Sciences, Geography Series*, 1969, No. 5.
- Biogeographic and Landscape Studies of Forest-Steppe*, Nauka Publishers, Moscow, 1972.
- Budyko, M. I., *The Heat Balance of the Earth's Surface*, Leningrad, 1956.
- Drozov, A. V. "A Further Development of A. A. Grigoryev's Idea Concerning the Role of Balance Methods in Physical Geography", *Transactions of the USSR Academy of Sciences, Geography Series*, 1975, No. 2.
- "Concerning the Study of Mass and Energy Exchanges in Landscapes with the Balance Methods", *Transactions of the USSR Academy of Sciences, Geography Series*, 1974, No. 1.
- Gerasimov, I. P., "A Constructive Geography: Goals, Methods and Results", *Transactions of the Geographic Society*, 1966, Issue 5.
- Soviet Geography. Results and Further Tasks*, Geografiz, Moscow, 1960.
- "The Scientific Foundations of Today's Environmental Monitoring", *Transactions of the USSR Academy of Sciences, Geography Series*, 1975, No. 3.
- Gerasimov, I. P., Isakov, Yu. A., Panfilov, D. V., "The Material Cycle within Major Types of Natural Ecosystems of the USSR", *Transactions of the USSR Academy of Sciences, Geography Series*, 1972, No. 2.
- Grin, A. M., *The Dynamics of the Water Balance of the Central Chernozem Region*, Nauka Publishers, Moscow, 1965.
- "Infiltration Properties of Soils and Intrazonal Features of the Structure of the Water Balance", *Transactions of the Geographic Society*, 1971, Issue 5.
- *Methods of Studying the Water Balance*, 1973.
- Grin, A. M., Evlakhina, M. I., Kuk, Yu. V., "The Character of the Penetration to the Level of Ground Waters in the Central Forest-Steppe Region", *Transactions of the USSR Academy of Sciences*, 1975, No. 5.
- Grin, A. M., Rauner, Yu. L., Utekhin, V. D., "The Effectiveness of the Use of Radiation and Moisture in the Formation of Organic Production in the Principal Ecosystems of the Central Forest-Steppe Region", *Transactions of the USSR Academy of Sciences, Geography Series*, 1970, No. 4.
-

- Grin, A. M., Savelieva, T. A., "Hydrometeorological Factors in the Biological Productivity of Forest-Steppe Field Ecosystems", *Transactions of the USSR Academy of Sciences, Geography Series*, 1971, No. 1.
- Grin, A. M., Savelieva, T. A., Chernyshev, E. P., "The Structure of the Water Balance of the Principal Natural Ecosystems of the Central Forest-Steppe Region and Its Connection with Biological Productivity", *Transactions of the USSR Academy of Sciences, Geography Series*, 1972, No. 2.
- Grin, A. M., Tiuleneva, V. A., "The Effectiveness of the Use of Water, Heat, and Mineral Nutrients in the Production of Biomass in Elementary Natural-Technical Complexes of the Central Forest-Steppe Region", *Summaries of the Papers Presented to the VI Congress of the USSR Geographic Society*, Tbilisi, 1975.
- Grinberg, V. M., Utekhin, V. D., "Some Approaches to the Mathematical Interpretation of the Internal Structure of Phytocoenosis", *Transactions of the USSR Academy of Sciences, Geography Series*, 1974, No. 2.
- Kokovina, T. P., *The Water Regime of Fertile Chernozem Soils and Water Supply of Their Crops and Cereals*, Kolos Publishers, Moscow, 1974.
- Rauner, Yu. L., *The Heat Balance of Plant Covers*, Leningrad, Gidrometizdat, 1972.
- Rauner, Yu. L., Ananiev, I. P., Samarina, N. N., "Energy Characteristics and the Effectiveness of Grain Crop Productivity", *Transactions of the USSR Academy of Sciences, Geography Series*, 1975, No. 3.  
*The Heat, and Radiation Balance of Natural Vegetation and of Agricultural Fields*, Nauka Publishers, Moscow, 1965.
- Utekhin, V. D., *Primary Biological Productivity of Forest-Steppe Landscapes* (Abstract of the candidate dissertation), Moscow, 1973.
- Zlotin, R. I., Khodasheva, K. S., *The Role of Animals in Biological Cycle of Forest-Steppe Ecosystems*, Nauka Publishers, Moscow, 1974.  
*Studies of the Genesis of Climate*, Institute of Geography Press, Moscow, 1974.

### **III.**

## **GEOGRAPHIC ASPECTS OF MAJOR ECOLOGICAL PROBLEMS**

---



**NATURAL HAZARDS ON THE TERRITORY OF THE USSR:  
STUDY, CONTROL AND WARNING<sup>1</sup>**  
(written jointly with T. B. Zvonkova)

Natural hazards originate in highly dynamic processes whose elemental nature expresses itself in their unpredictable and uncontrollable character. Those natural hazards that cause losses of human life and great material damage to economies are called disasters and catastrophes. Two aspects of such natural hazards are noted: their potential for disaster and their actual catastrophic results. Not all potentially dangerous hazards are disastrous. In contrast to their potential danger which remains the same, the intensity of disasters is governed by five major factors:

1. Historical and social conditions, as well as the level of economic development of a country or a region, which affect their vulnerability. In developing countries even potentially modest hazards may prove disastrous. For example, at the beginning of the century, barkhan sands caused great damage in Central Asia by disrupting irrigation systems and also covering some towns. Today, while eolian processes are no longer viewed as disastrous they continue to be destructive in the Republics of Soviet Central Asia. For example, the cost of clearing sand from 500 meters (1,600 feet) of a railway line in the western part of the Kara-Kum desert in 1966 was about 100,000 rubles (about U.S. \$ 110,000). Subsequently the railroad was removed from the zone in which sandstorms developed. Today, neither towns nor agricultural fields in Soviet Central Asia are covered with sand.

<sup>1</sup> G. F. White, ed., *Natural Hazards. Local, National, Global*, New York, London, 1974.

2. The scope of the damage that natural hazards may cause derives from forms of land use. It matters who and what are exposed to natural hazards. In the case of railways and highways, for example, a snow cover of 400 millimeters (16 inches) will disrupt operating conditions and will require a large volume of work. But the same depth of snow cover is beneficial to winter crops.

3. The scope of disasters through natural hazards depends on a region's geographic position within a sequence of processes. In the European part of the USSR, for example, winter crops are destroyed by frost when the snow cover is less than 300 millimeters (12 inches), while in Siberia they will be damaged when the snow cover is 400-500 millimeters thick (16-19 inches). A complex, economically detrimental situation develops in West Siberia when the usual sequence of frost and snow is perturbed in water logged areas. In particular when soils containing peat are covered with snow it is nearly impossible to transport wood, petroleum equipment and other products. In the recent past this was disastrous for the inhabitants of the Tyumen region. Today "Antei" planes and helicopters are used to minimize the effects of potentially disastrous situations.

4. Natural hazards are often not so dangerous when taken separately but cause predicaments when combined with other processes. In the Magadan region outdoor work ceases when temperatures of  $-35^{\circ}\text{C}$  ( $-31^{\circ}\text{F.}$ ) are combined with strong winds. Landslides on the Black Sea coast would not be disastrous if they were not combined with an intense erosion of the shoreline.

5. In most cases the scope of disasters produced by natural hazards is governed not by a single characteristic but by the scale, duration and intensity of corresponding phenomena. While natural hazards are always potentially disastrous actually resulting damage will vary in accordance with social, economic and geographic conditions.

In studying the problem of natural hazards the relevance of modern scientific and technical advances as well as the growing influence of human activities on the natural environment should be recognized. These activities perturb and modify nature's original dynamic state. As a result the self-regulating properties of natural processes either vanish or are weakened. It would be logical that having disturbed the environment's natural state man should also assume corresponding regulation functions.

The polygenetic character of natural hazards on the territory of the USSR derives from its diversity of natural conditions. Potentially disastrous natural phenomena in the USSR are also closely associated with certain regions and geographic zones.

Such phenomena often develop at the interface of physically different natural environments: sea and land, atmosphere and ionosphere, etc. Potentially dangerous regional processes originate in volcanism, earthquakes, tsunamis, mudflows, avalanches, floods and hurricanes. In some regions these phenomena produce considerable material damage as well as losses of human lives.

### **VOLCANISM**

Recent instances of volcanic activity in the USSR have only been recorded in the Far Eastern regions, namely, in Kamchatka and the Kuril Islands (38 volcanoes). Most of these volcanoes have erupted periodically in the form of lava emissions and expulsion of rock fragments ("bombs"), sand, ashes and gas. Most major earthquakes, occurring every 7 to 10 years, referred to the Kliuchevski group of volcanoes and to the Karymski and Avachinski volcanoes.

While the eruptions in Kamchatka and the Kuril Islands were quite strong they did not produce major damage, since these areas have never been densely populated. A number of well-known methods for studying and forecasting volcanic activity exist. Major research activities are carried out at the Institute of Volcanology in Kamchatka and at the USSR Academy of Sciences's Institute of Earth Physics.

### **EARTHQUAKES**

As much as 20 per cent of the USSR's area is subject to earthquakes with an intensity of more than 8 points (that is a force shock) on the Soviet Academy of Science's intensity scale. Above all these are the largely mountainous areas of the country's south and Far East: Kopetdag, Tien Shan, the Pamirs, south Siberia, Kamchatka, and the Kuril Islands. Approximately 20 per cent of the USSR's population lives in these areas, which include such cities as Tashkent, Alma-Ata, Dushanbe, and Irkutsk.

Earthquakes with an intensity of 6 to 8 points occur in the Carpathians and in the Crimea mountains. In the

Carpathians the principal earthquake area is a sharp bend in the mountain ridge. In the Crimea they are confined to the southern shore, i.e., to the zone of a great fault.

While more intensive earthquakes also occur in the Caucasus (up to 8 to 11 points) most of them have a force of 6 to 7 points. They occur in the volcanic uplands of Transcaucasia and on the periphery of the Kuro-Araksian hollow. Major cities in Soviet Central Asia that have been damaged by catastrophic earthquakes of 9 to 10 points include Vernyi (Alma-Ata) (1887, 1911), Krasnovodsk (1895), Andizhan (1902), Dushanbe (1903), Fergana (1907, 1946), Ashkhabad (1929, 1948), Kazandzhik (1946) and Tashkent (1966).

In the mountains of South Siberia the force of earthquakes varies from 6 to 9 points. Most of them are confined to the Lake Baikal basin and to the surrounding drift zone. Destructive earthquakes in this area took place in 1814, 1902, 1908, 1931, 1946 and 1959. Numerous earthquakes with an intensity of 8 to 9 points have also taken place in Kamchatka and the Kuril Islands.

The various destructive consequences of earthquakes are widely known. When strong earthquakes occur in major cities large numbers of houses are destroyed and thousands of people perish. Major forms of damage occurred in the city of Vernyi in 1911; in Ashkhabad in 1948; and in Tashkent in 1966, although losses of human lives were not numerous. Earthquakes, however, cause other, grim forms of damage: the destruction of roads, bridges, canals, and dams and the activation of mountain avalanches, landslides, and earth fissures. Many dammed lakes are formed in the mountains of Central Asia and the Caucasus during strong earthquakes.

At the present time the USSR possesses a well developed seismological service that accurately records movements of the Earth's crust that are caused by earthquakes. That service has accumulated large volumes of information. When combined with a diversity of geological and geophysical data this provides a basis for both a general and a detailed seismic zoning of the USSR which aids in designing earthquakeproof buildings and in carrying out other protective measures.

Today major research efforts in the USSR are concerned with improving methods for forecasting the exact location and time of earthquakes by detecting preceding developments. This has led to studies of recent tectonic movements of the Earth's surface in seismic regions through

repeated land surveys with high precision measuring devices. Detailed studies are also being carried out of all the symptoms of changes in the Earth's crust that precede earthquakes (the relation of linear to transverse waves, of electric to magnetic fields, geochemical phenomena). While these studies have not yet provided conclusively reliable results they appear to be highly promising.

## TSUNAMIS

Tsunamis are long waves that are caused primarily by seaquakes and volcanic activity. They have been very dangerous for the population of the shorelines of Kamchatka, the Kuril Islands, and Sakhalin. Tsunamis appear suddenly and move with a velocity of about 400 to 500 kilometers per hour (250-300 mph). As they approach the coastline their waves form a series of rolling waves (3-7) whose average height is 5-10 meters (15-30 feet). Waves as high as 20 meters (65 feet) develop along small coastal areas, usually in bays of the fjord type.

*Table 9*

**Material Transported by Selected Seli in the USSR**

River	Volume in m <sup>3</sup>	Washed material in m <sup>3</sup> per km <sup>2</sup> of area of active seli formation
Chkheri River (Caucasus)	1,440,000	180,000
Kishgei River (southern slope of the Greater Caucas Range)	3,000,000	120,000
South Kazakhstan	3,500,000	30,000

Particularly strong tsunamis were recorded on the territory of the USSR in 1737, 1780, 1898, 1918, 1923, 1952 and 1963. The degree of danger of tsunamis has varied greatly and reflects not so much the strength of seaquakes as elements of relief and ocean depth along the routes that they follow.

There is a tsunami warning service in the USSR that relies on two principal methods for detecting their location: seismic and hydroacoustic. Because the velocity of seismic and hydroacoustic waves is much greater than that of tsunamis themselves, it is usually possible to issue alarm signals 30-40

minutes in advance. It is fortunate that the areas of rocky bays in Kamchatka that can contribute to tsunamis are not populated.

### MUDFLAUS

In terms of damage caused to the economy by mudflows or seli in mountain regions the USSR holds a leading place. These are concentrated in the North Caucasus, Transcaucasia, the mountains of Soviet Central Asia and eastern Kazakhstan, the Crimean mountains, the Carpathians and the region adjoining Lake Baikal.

Mudflows occur suddenly and rapidly and carry large volumes of loose material, mud and water along mountainous rivers. As indicated in Table 9, the volume of solid matter transported in this manner may be as large as 180,000 cubic meters (6.4 million cubic feet) originating in 1 square kilometer (0.4 square mile) of active seli formation.

Hundreds of destructive seli have been recorded during the last 80 years, some of them catastrophic. This is true, for example, of the glacial seli that developed in July 1963 in the central part of the Zailiyski Ala-Tau. Its runoff of almost a million cubic meters or 35 million cubic feet completely filled the basin of Issyk Lake. The loose strata were 25 meters thick (80 feet). Seli that developed in the Fergana Valley in March 1965 and in the North Caucasus in August 1967 led to major floods. Finally, in 1971 a destructive seli developed in the region of the Kruglo-Baikal railroad. Large cities in the USSR located in dangerous seli areas include Alma-Ata, Yerevan, Dushanbe and Frunze.

A number of general observations may be made concerning the distribution of seli within the USSR: (1) They are associated with areas of the latest and most of recent mountain folding. (2) There is a close relation between seli and heavy snowfall or sudden thaws, particularly in medium-sized and low mountainous areas that are not fed by glacier alimentation. Such types of torrent are most widespread. (3) Disastrous glacial seli originate in areas of old and recent moraines at times of maximum ice melting rates (July-August). (4) Seli are related to earthquakes as well as to avalanches and landslides, which increase the danger of mud and stone-laden torrents. (5) Various types of misuse of mountain slopes, such as the elimination of forests, intensify the potential development of seli.

Seli studies in the USSR seek to establish the potential danger of seli in particular areas and to forecast seli phenomena. They are also concerned with forms of protecting such areas through the construction of protective installations.

Corresponding protective measures include: (1) organisational and technical measures such as restrictions on tree-felling on mountain slopes, the establishment of forest reservations, the regulation of pasture use, and artificial snow melting; (2) improvements in forestation and the planting of forests on slopes to prevent erosion, the regulation of surface runoff and terracing; (3) the construction of jump dams to soften slopes of trap filters to retain fragmented material, and also of channeling dams.

In regions where seli are especially dangerous forecasts are made by hydrometeorologists. In the region of Alma-Ata, for example, there is an automatic radio-telemetric seli detection station. A unique 100-meter (330-foot) mountain earth dam for retaining disastrous seli has also been built in that area.

#### **SNOW AVALANCHES AND DISASTROUS SURGES OF GLACIERS**

Slides of large masses of snow are widespread and continuous not only in high mountain areas of the Caucasus and the Tien Shan, but also in the moderately high and low mountain regions of the Khibin, Urals, Sykhote-Alin, and Kamchatka.

But snow avalanches occur most frequently in areas of recent glaciation whose slopes carry heavily encrusted snow. In such places avalanches move down along the same route one or more times each year. There are three types of avalanches: sluff, channeled and jumping. The last of these is especially destructive. Such avalanches move rapidly and possess a strong impact.

While avalanches are very numerous not all of them are hazardous. Disasters result from combinations of heavy and continuous snowfall with strong winds. Under such conditions snow accumulates in unusual places and then slides down along slopes. While disastrous avalanches are not frequent they are highly destructive. This was true, for example, of the snow avalanche in the vicinity of the town of Kirovsk (Khibin Mountains) that moved down along the slopes of the Aiquaiventchorr Mountain on December 22,

1936 carrying 285,000 cubic meters of snow (10 million cubic feet). In that case there were persistent southward winds blowing at a rate of 3 to 12 and even 20 meters per second (6 to 25 and even 40 mph) and daily additions to the snow cover reached 100 millimeters (16 inches). Major avalanches have also occurred along the southern slopes of the Kuril Islands on December 25, 1959, and along the western Caucasus mountains in the winter of 1962-63. Stormy winds (40 meters per second or 80 mph) contributed to the former by shifting snow masses towards the slope. In the Caucasus heavy snowfalls of 2 meters (6.5 feet) and winds contributed to the avalanche.

When studies of avalanches and also some other natural hazards were initiated questionnaires were sent to corresponding institutions and to regions that had been poorly studied in this respect.

The following questions were asked:

1. Do you know places where avalanches took place?
2. Describe the avalanche areas: steep or gently sloping, their height, orientation (to the south, west, etc.), presence of forests along the slope.
3. Describe the avalanche: size, snow in the avalanche, destructive outcome.
4. How often did you happen to observe avalanches in the region that you describe? Record the dates on which they occurred (date, month, year).
5. What kind of weather preceded the avalanche?
6. What was the height of the snow cover in places in which the avalanche originated?

There have been considerable advances in recent years in the USSR in studies of avalanches. These include: (1) forecasts of the threat of avalanches on the basis of geomorphological, geobotanical, soil, and hydrogeological properties of individual areas; (2) soundings and stratigraphic studies of snow masses; (3) analyses of synoptic situations; (4) data estimates concerning relevant meteorological conditions and changes in the snow cover; and (5) photogrammetry. "

The effectiveness of protective measures increased substantially when they were extended to large areas. They include warning services in regions that are particularly dangerous, and preventive measures to channel avalanches into safe directions by using mortars or chemical reagents. Other measures include development activities designed to retain accumulating snow on the slopes (by such measures as

forest planting) and the direct protection of individual objects against avalanches.

Disastrous surges of so-called pulsating glaciers occur in the Pamirs, the Tien Shan mountains and the Caucasus. They are highly dangerous because of their suddenness as well as their destructiveness. Comprehensive surge studies have been carried out at Medvezhii in the Pamirs since 1963, and at Kolka in the Caucasus since 1970. A 7-kilometer (4 mile) protrusion of the Medvezhii glacier moves rapidly every 12-14 years. That glacier advanced 1,600 meters (5,300 feet) along a valley during its last surge in 1963, and brought 140 million cubic meters of ice (5 billion cubic feet) into the lower part of its protrusion. Surges of the Kolka glacier take place every 65-70 years.

While such surges are not dangerous to life because of their time rhythm (1-10 kilometres per year) (0.6-6 miles per year), however, together with the resulting seli they cause economic damage. At the present time there are no technical means for controlling them. It is hoped that forecasting such developments will become possible in the future.

## FLOODS

While snow and rain produce high levels of waters on large rivers nearly every year usually this does not produce serious damage. Damage is largely avoided through various forms of regulating river runoff and through such measures as damming, blasting of ice blocks, etc.

There are, nevertheless, some regions where high water river floods are disastrous under certain hydrometeorological conditions. Generally these are areas in which adjoining rivers develop high levels at different times. For example the rivers of western Siberia and especially the tributaries of the Irtysh and Ob rivers, which are subjected to late floods, temporarily reverse their courses when their channels are blocked by ice. In the mouth of the Yany River southern floodwaters overflow an ice bed of the oceanic shelf, spread over the surface, and inundate the floodplain terrace. Similar summer and autumn high waters in the basins of the Amur, Zeya, Bureya, and other rivers of the Soviet Far East are produced by continuous monsoon rains. There catastrophic floods occur approximately once every 7 years.

Such floods are partly attributable to abundant detrital deposits in lower reaches of a river. In particular, the

Amu-Darya possesses a very steep gradient of its water surface and a high volume of suspended detrital material that exceeds the solid contents of the Nile as well as that of all rivers of Soviet Central Asia. This produces a heavy deposition of loose material. The river, which is higher than adjacent areas, submerges floodplains at times of high water. New channels then form as banks are destroyed. In some cases floods are caused by wind surges at the mouths of rivers (for example the River Neva).

Since disastrous floods are thus caused by a variety of factors, preventive measures require a wide range of land improvement activities and hydrotechnical facilities. A major role is played by the long-term regulation of the rivers' run-off. Corresponding dams and water reservoirs have been constructed on the Zeya, Amur, Bureya, Selemdzhe, and many other rivers.

### HURRICANES

There are catastrophic hurricanes (with a wind velocity over 29 meters per second or 60 mph) almost each year in various parts of the USSR. They usually originate in cyclones (when there is an advance of cold air) on cold fronts or else on the periphery of anticyclones. Such winds arise unexpectedly and produce storms at sea and on land (often thunderstorms) as well as intense rainfalls. In steppes and arid zones they generally produce dust storms that greatly intensify the deflation of plowed soils. In the southern part of Soviet Central Asia strong hot winds are called "afganets".

Hurricanes bring vast destruction to property and occasionally to human life. Such losses decline, however, as the reliability of corresponding weather forecasts decreases. Insurance payments are made by the government for damages caused by hurricanes with a wind velocity of more than 15.3 meters per second (or 34 mph). This is 8 points on the corresponding scale.

Still other natural phenomena that are associated with particular geographic zones include droughts, dry winds, heavy snowfalls and low temperatures. These processes are usually confined to relatively small areas and may be disastrous even if they occur only once. The corresponding zonal processes are catastrophic over wide areas, recur frequently, and may be prolonged. They are most pronounced when external meteorological factors are incompatible with

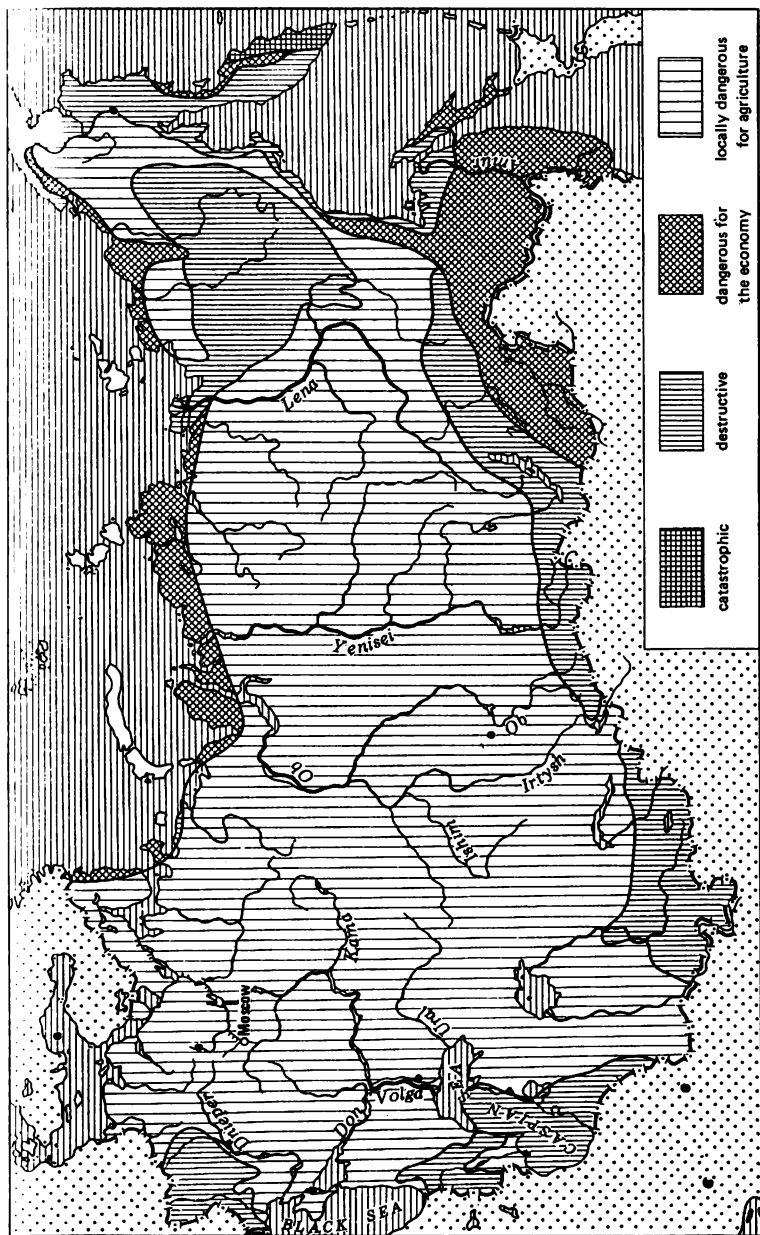


Figure 6. Probability of Drought (per cent), according to V. A. Smirnov (1958)

local conditions. While these phenomena are usually not disastrous they frequently cause considerable economic damage.

### DROUGHTS AND DRY WINDS

Both droughts and dry winds are relatively frequent (Fig. 6) in forest-steppe and steppe zones in which there is a considerable gap (during the vegetation period) between a great energy potential for transpiration of cultivated plants and small reserves of soil moisture. In forest steppe zones droughts, usually, occur once or twice every 10 years. In the steppes they recur five to six times every 10 years. They are generally severe and may recur 2 or 3 years in succession (1906-1908, 1938-1939, 1950-1951, 1954-1955). In forest-steppe and steppe zones of the USSR where cereal crops prevail, droughts are studied from an agroclimatic point of view that includes biological and physiological aspects of this phenomena. Indices of drought intensity correspond to reductions in harvests: up to 20 per cent for minor drought; 20-50 per cent for moderate droughts; and over 50 per cent for severe droughts. Droughts cause great damage to agriculture, but because the area of the Soviet Union is very extensive crop failures in one region may be compensated by favourable conditions in others.

Droughts are frequently aggravated by severe dry winds. At such times there is an exceptionally large deficiency of moisture in the air as well as high wind velocities and insufficient reserves of productive soil moisture. Dry winds are very intense when the deficiency in air moisture reaches 40 millimeters (1.6 inches), wind velocity is at least 10 meters per second (20 mph) and productive moisture reserves decline to 0-30 milliliters (0-1 fluid ounce).

Droughts and dry winds have been studied for a long time, and extensive statistical material has made it possible to produce maps of recurrence of droughts and dry winds in the USSR. Such maps help determine the probability of corresponding phenomena in any particular year. An example of dry wind recurrence analysis is given in Table 10.

A basic means for protecting agricultural lands against drought is irrigation. Large-scale irrigation projects transfer water from basins in areas possessing excessive moisture to deficit areas. Additional measures to reduce the influence of droughts and dry winds include the development of

**Characteristics of Dry Winds in the USSR**  
(according to E. A. Tsuberbiller)

Zones	Intense	Average duration of non-productive period (in days)	Average reserves of productive moisture in 1 m layer of soil (ml)	Probability of damage to crops (%/yr)
		Moderately intense		
Forest	0.1-0.3	0 1.0	60-100	0-10
Forest-steppe	0.3-0.6	1.0-2.0	50-60	10-20
Moderately arid	0.6-1.5	2.0-4.0	30-50	20-30
Arid	1.5-3.0	4.0-6.0	20-30	30-50
Semidesert	3.5-5.0	6.0-10.0	10-20	50-70
Desert (northern part)	5.0	10.0	10	70

protective forest belts, the retention of spring snow, fallow lands, contour plowing (to regulate surface runoff), strip farming, the microterracing of slopes, and the selection of drought-resistant crops.

Abnormally low temperatures in autumn and spring as well as winter periods may be viewed as natural hazards. But disaster criteria for all these processes differ considerably for various zones and economic objects. On the pastoral lands of Soviet Central Asia, for example, grazing stops in winter, when temperatures are  $-16^{\circ}\text{C}$ . and wind velocity is 10 meters per second (3 F., 20 mph) or else  $-27^{\circ}\text{C}$ . with a wind velocity of 5 meters per second ( $-17^{\circ}\text{F}$ ., 10 mph). In the northern part of the country outdoor work is prohibited at temperatures of  $-35^{\circ}$  to  $50^{\circ}\text{C}$ . ( $-31^{\circ}$  to  $-58^{\circ}\text{F}$ .) with no wind.

An index of abnormally severe winters is provided by the probability that minimum seasonal air temperature will be less than  $-30^{\circ}$  to  $-40^{\circ}\text{C}$ . ( $-22^{\circ}$  to  $-40^{\circ}\text{F}$ .). Even when there is almost no wind this limits cattle grazing in the winter. Such temperatures are dangerous for crops and may destroy machinery and other equipment.

While seldom disastrous, abnormally low temperatures create additional expenses for establishing winter enclosures for cattle and machinery.

## HEAVY SNOWFALLS

Heavy snowfalls are accompanied by a continuous transfer of large masses of snow and are viewed as natural hazards in some regions of the USSR. Snowfalls that increase the height of snow cover by more than 100 millimeters (4 inches) have been recorded most frequently in Kamchatka (286 cases). There are also well-known areas of extensive snow transfers (over 1,500 cubic meters per meter of length, or 53,000 cubic feet per foot of length) (Fig. 7). Considerable volumes of snow (900 millimeters or 35 inches) and prolonged snow falls have also been recorded. The most susceptible areas include the northern part of West Siberia (particularly the Taimir), as well as the southern part of West Siberia and Kazakhstan (1,000 cubic meters per meter, or 35,000 cubic feet per foot). Extremely heavy snowstorms occur in Anadyr (3.10 cubic meters per meter per hour, or 110 cubic feet per foot per hour) and in Petropavlovsk-Kamchatsky (2.55 cubic meters per meter per hour, or 90 cubic feet per foot per hour).

While heavy snowfalls seldom result in a loss of human life, they do require expensive snow clearing activities on railroads and highways. Large volumes of snow also increase pressure on buildings' roofs, and early snowfalls occurring before forests have lost their foliage may cause winds to fell entire trees (e.g., as in the autumn of 1971 in the vicinity of Moscow). The greatest density of snow cover (over 0.30 grams per cubic centimeter, or 0.17 ounce per cubic inch) has been recorded along the coastlines of northern seas and the eastern coastline of Kamchatka (0.36 grams per cubic centimeter, or 0.21 ounce per cubic inch). Approximately 20 per cent of rail lines in the USSR in regions of heavy snowfall are protected by wooden shields while remaining parts are effectively protected by forests.

While there are other natural hazards on the vast and diverse territory of the USSR, they are either local in character or cause comparatively insignificant damage.

Nearly all natural hazards lie beyond any direct dependence on men's activities. Some may partly accelerate or reduce their intensity in response to man's economic activities (for example seli) but air and water pollution and so-called anthropogenic forms of soil erosion are not encompassed by the processes being considered, which are not natural hazards, but anthropogenic processes. The latter

are caused by man's misguided attitudes towards the environment. That problem requires a separate study.

An analysis of natural hazards in the USSR shows the prevalence of typical combinations. The country's plains are characterized by droughts whose probability ranges from 10 to 30 per cent, spring or autumn frosts (2-6 years out of 10), snowstorms, heavy snowfalls and many other phenomena. Mountain areas are characterized by seismic processes, snow avalanches, and seli, while sea shores are subject to hurricanes (40-50 meters per second or 80-100 mph) and tsunamis.

Differences in prevailing combinations of various types of natural hazards have led to the identification of 29 corresponding regions in the USSR. These are classified into four groups according to the intensity and outcomes of corresponding natural hazards: regions of the 1st type in which catastrophic natural hazards occur that may produce a loss of life and major damage to the economy (volcanic activities, earthquakes, tsunami); regions of the 2nd type, whose destructive natural phenomena seldom cause loss of life but may produce significant economic losses, mainly in industry (earthquakes, hurricanes, seli, avalanches, and floods combined with other natural processes); regions of the 3rd type that are marked by economically dangerous natural processes (droughts, floods, hurricanes, seli); and regions of the 4th type in which local development of natural hazards causes damage primarily to agriculture (late and early frosts, heavy rains, winds) (Fig. 7).

It has already been mentioned that considerable efforts have been initiated in the USSR to establish warning systems and carry out protective measures. But natural hazards have not been eliminated. Accordingly both persons and agricultural and industrial enterprises that suffer from natural disasters receive insurance payments from the government. The state insurance company "Gosstrakh"—State Insurance (which does not seek profits from insurance operations) provides insurance against the following types of disaster: earthquakes, floods, lightning, hurricanes, seli, avalanches, downfalls, landslides, droughts, mud-laden torrents, heavy rains, hail, early autumn frosts and late spring frosts. Agricultural land is insured not only against these possibilities but also against the silting of soils, frosts, windless weather during pollination periods, etc. Similarly animals in the extreme south of the country as well as the extreme north are

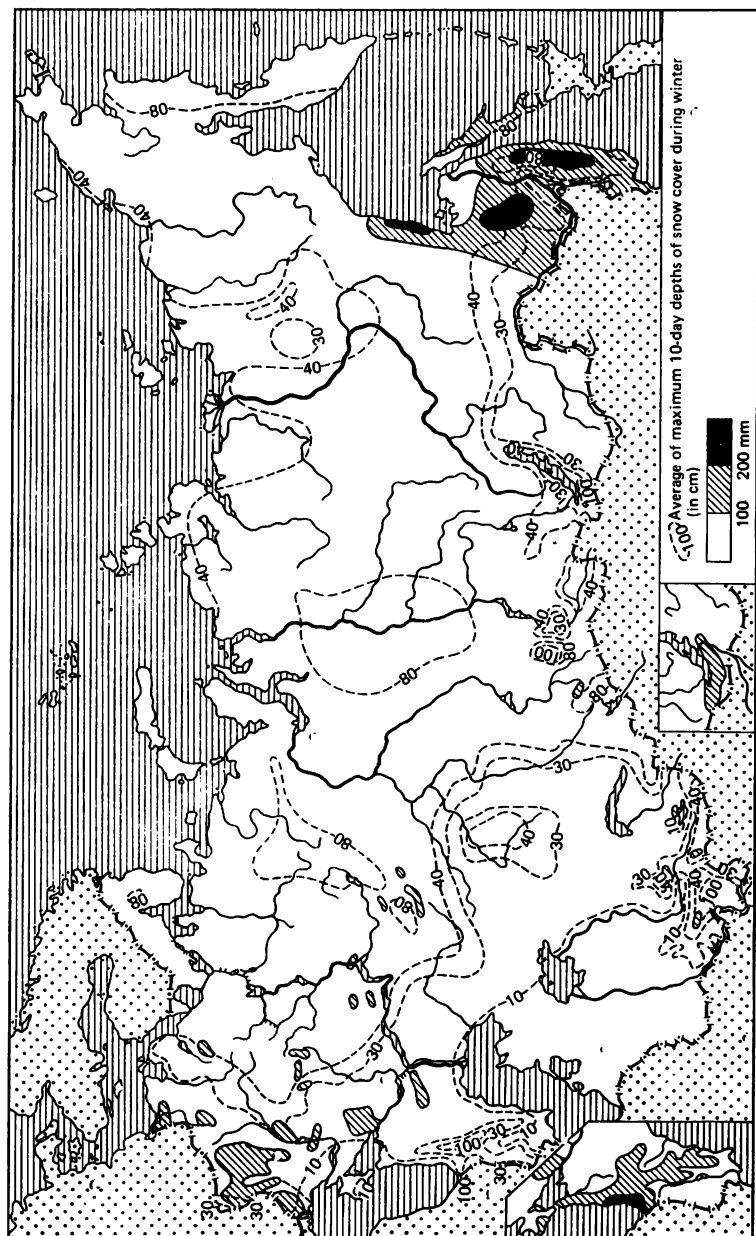


Fig. 7. Areas of Varying Natural Hazard Intensity in the USSR

insured against damage caused by ice-crusts on ground, thick snow, frozen snow crust, etc. According to insurance terms introduced in 1967, the government compensates agricultural institutions for all damages associated with losses of animals or crop failure, and also destruction of buildings caused by natural processes not peculiar to the given region. By January 1, 1970 the total insurance that was paid for damages to all types of personal domestic property was 78.5 billion rubles, and a similar sum was paid for damages to collective farm property.

## **Bibliography**

(in Russian)

- Goldberg, I. A., *Agroclimatic Characteristics of Frosts in the USSR and Methods of Control*, Gidrometeoizdat, 1961. *Droughts in the USSR, Their Origin, Recurrence and Influence on Crops*, Gidrometeoizdat, 1961. *Earthquakes in the USSR*, USSR Academy of Sciences Publishers, 1961-1966. *Engineering Glaciology*, Moscow University Press, 1971.
- Karyakin, V. A., *Avalanche Prone Areas of the Soviet Union*, Moscow University Press, 1970. *Determination of Place of Tsunami Occurrence*, Gidrometeoizdat, 1971.
- Linovskaya, V. I. "Weight Distribution of Snow Cover", *Transactions of the Geographic Society*, Vol. 210, 1967.
- Losev, K. S., *Avalanches of the USSR*, Gidrometeoizdat, 1966.
- Mikhel, V. M., Rudneva, A. V., and Linkovskaya, V. I., *Snow Transfer during Snowstorms and Snowfalls on the Territory of the USSR*, Gidrometeoizdat, 1969.
- Mikhel, V. M., Rudneva, A. V., and Linkovskaya, V. I., *State Insurance in the USSR* (A group of authors under the guidance of L. A. Motylev), Finansy Publishers, 1971.
- Milevsky, V. Yu., "Probability of Winds of Different Velocity on the USSR Area", *Transactions of the State Meteorological Institute in Leningrad*, Vol. 12, 1961.
- Nalivkin, D. V., *Recommendations on Control Against Wind and Water Erosion of Soils*, Agricultural Academy Press, 1964. *Mud-laden Torrents in the USSR and Measures Against Them*, Nauka Publishers, 1964. *Recent Volcanism*, Nauka Publishers, Vols. 1-2, 1966. *Dry Winds, Their Origin and Control*, USSR Academy of Sciences Publishers, 1967. *Hurricanes, Storms and Whirlwinds*, Nauka Publishers, 1969.

## THE UNITED NATIONS CONFERENCE ON DESERTIFICATION

The United Nations Conference on Desertification was held in late August-early September, 1977 in Nairobi, Kenya. This was a comprehensive and prolonged scientific-technical as well as socio-political forum. Approximately 100 countries and 80 intergovernmental and nongovernmental organizations sent their scientists, engineers, statesmen and public figures. Altogether some 1,500 persons participated in the Conference.

Its convocation was prompted by the catastrophic drought that affected vast areas to the south of the Sahara desert in 1968-1973. This arid and subtropical zone is usually called the Sahel. There are often droughts in this region and sometimes they are quite severe (for example in 1911 and 1940). The drought of 1968-1973, however, was unusually prolonged and constituted a national disaster for many African countries located in the Sahel zone, and especially for such countries as the Senegal, Mali, Mauritania, Niger and Chad. Its consequences were truly dramatic. In particular the water surface area of the Chad, a great African lake, declined to two thirds of its normal size; major African rivers, the Niger and the Senegal rivers, which flow through the Sahel zone, completely ceased to flood during high water seasons; and very large numbers of wells supplying drinking water were depleted, while surface reservoirs normally accumulating rain water vanished completely. Natural pasture lands lay waste as their feeding capacity declined sharply; and everywhere shrubs and trees died from lack of moisture.

In many African countries this drought brought enormous losses to cattle raising and to rain-fed agriculture. Shortages of water and of fodder led to the loss of large herds of livestock. There was a catastrophic crop failure affecting food supplies. Destitute, famine-stricken populations abandoned their traditional settlements and sought refuge in towns. Approximately 250,000 residents of the Sahel zone died from famine.

International aid was given to residents of afflicted areas, especially in the form of food and medicine. At the same time the enormous scale of this environmental hazard and the corresponding damage drew the attention of world public opinion. UNESCO and FAO carried out a survey of the catastrophe, and in 1974 African countries persuaded the United Nations General Assembly to adopt a resolution proposing to consider the state of arid territories throughout the world and to develop measures to combat environmental hazards ("desertification") in these regions. This is why four regional conferences were held on these issues before this was followed in 1977, by a concluding World Conference on Problems of Desertification.

The work of the Conference on Desertification was based on scientifically prepared survey data contributed by international organizations. They included:

- Desertification: An Overview;
- World Map of Desertification on a 1:25 million scale, together with a short commentary;
- Draft Plan of action to combat desertification.

Let us consider these documents more closely. The general survey was a synthesis of four independent parts entitled: "Climate and Desertification"; "Ecological Changes and Desertification"; "Population, Society and Desertification"; and "Technology and Desertification".

A definition of the concept of desertification is presented in the general survey of corresponding processes: "desertification is a long-term decline in the land's biological productivity". That definition, however, is not viewed as final, and discussions concerning a more precise definition of that term continue to take place, since, as was noted in the documents being considered, even "asphalt roads destroy the biological productivity of soils".<sup>1</sup> Nevertheless, the definition

---

<sup>1</sup> As will be shown later a more rigorous term would be "depletion" rather than "desertification".

given above is employed in the documents of the Conference. It is made more precise only with regard to specific geographic contexts (it refers to "the world's arid or dry territories") and also in an anthropocentric sense. That detailed definition reads: "Desertification represents a process leading to a decline in biological productivity and to a consequent reduction in plant biomass in relation to the land's carrying capacity for livestock, in crop yields, and human well-being" (commentary to the Desertification Map).

It is recognized that the basic cause for the development of desertification processes is human impact that disrupts the nature of arid lands. According to the overview under consideration this impact is generally attributable to objective factors. The latter include, above all, population growth and corresponding increases in needs, as well as the requirements of market (commercial) production activities that lead to an intensification in the use of natural resources of arid territories. This also includes environmental hazards, such as droughts. Accordingly, "desertification is a problem of interaction between complex and unstable environments of arid territories used and inhabited by human populations that results from their attempts to provide means of existence".

One of the most important forms of commercial use of arid lands concerns pastoralism and especially its seasonal forms. This is why much emphasis is given to this problem in the overview. It is stressed that because it is traditional in many regions of the world, and especially in developing countries, pastoralism practices have developed a number of effective measures providing livelihood. But according to the overview during the past 50 years pastoral nomadism has found itself increasingly "at bay—socially, economically and politically". Nomadic economy "increasingly falls into a neglect" under the pressure of new requirements, pastoral lands decline, and pressure on their resources increases. As a result a degradation of natural ecosystems employed for cattle grazing has taken place throughout the world and has led to processes of desertification.

Actually, according to the overview, these very same processes, amplified by the influence of new technology, are also characteristic of more highly organized commercial ranging systems, since the tendency to maximize profit within such systems "readily leads to unreasonable overstocking". This produces a degradation of pastoral ecosystems and

a development of desertification processes in such production units as well.

In the case of rain-fed crop production systems on arid lands, desertification processes occur primarily through water and wind erosion and through a declining soil fertility attributable to the tillage, crust formation, etc. Finally, in the case of irrigated agricultural systems, the most threatening form of desertification concerns a secondary salinization of soils resulting from incorrect forms of watering and insufficient drainage. Desertification processes may also take the form of a deterioration in the water supply of arid lands, a decline in numbers of wild animals, and extensions of areas subjected to drifting sands, as well as a number of other destructive natural phenomena.

The principal conclusion of the overview prepared for the Conference is that desertification processes (which reduce the biological productivity of arid lands) are currently developing everywhere throughout the world at an accelerating rate. It is indicated that in the opinion of experts the rates at which lands are withdrawn from agriculture as a result of desertification is nearly 50 thousand square kilometers per year. If one considers that according to the World Map of Desertification the total area of potentially productive arid lands threatened by desertification is 45 million square kilometers, that is 30 per cent of the entire Earth's surface, and that it currently sustains 600-700 million persons, the scale of the problem and its socio-economic significance becomes apparent. It should be noted, however, that the quantitative estimates of desertification processes that are mentioned require a greater precision.

Both the "Plan of Action" and a special section of the Overview prepared for the Conference describe measures designed to actively oppose desertification.

The Overview contains scientific and technological prescriptions in developing arid lands that are well-known among specialists. In particular, it is recommended that in the case of pastoralism the grazing norms of domestic animals should be established in such a way as to anticipate the degradation of natural ecosystems. Also, that fodder reserves be created, that grazing lands be rotated and that water resources be employed more effectively. In the case of rain-fed cropping systems, it is recommended that forecasting information on droughts be developed; that drought-resistant crop varieties be employed; that maps of rational land use be

prepared; that clean-fallowing practices designed to accumulate moisture be adopted; that terrace farming methods be encouraged as well as special types of crop rotation and measures to oppose wind and water erosion. In the case of irrigated agricultural systems particular importance is attached to measures which oppose a secondary salinization of soils by relying on approximate norms of irrigation and on effective types of drainage. Particular emphasis is placed on the need to protect the environment of arid territories in cases when they are emphasized for mining operations and for tourism.

All this, of course, refers to generally known facts and does not really call for detailed analysis. The authors of the overview recognize this and stress that "past failures to maintain balanced livelihood systems in dry lands are the outcome of an inability to apply existing knowledge of physical processes rather than from any lack of understanding of these processes. This is true of the design of measures to combat desertification". Accordingly "plans of action should stress actions rather than future research".

Perhaps the only exception in this regard concerns the need to provide for a regular monitoring of the state of ecosystems of arid territories so as to anticipate desertification processes and identify the regions in which they are taking place. According to the Overview monitoring refers to a system of "worldwide surveillance carried out on a uniform basis in which data can be intelligibly exchanged". It is even called a "world desert watch".

One of the first steps based on such a monitoring should be the preparation of a map showing types of desertification and the relative vulnerability of the demarked ground units to the further development of these processes. Next, regional plans may be developed for measures to combat desertification in accordance with plans envisaging improvements in land use, the resettlement of populations, and other necessary measures. Beyond regional plans it is possible to develop concrete measures for combating desertification and also select sectors for carrying out pilot projects. "The Overview thus proposes the organization of a global geographical surveillance service to monitor the state of the natural environment on arid lands and base a rational utilization of their land, water and fodder resources on such a service.

The Conference's second working document – "World Map

of Desertification" was also prepared by experts in international organizations. Different colours were employed to show territories on which desertification processes are either taking place or else are possible, at rates that are shown as moderate, high, or very high. Indices are employed to describe the general nature of corresponding processes (moving sands, the deflation and erosion of rocky, alluvial and other surfaces, the secondary salinization of soils), and also their basic causes (human and technological pressure, the pressure of animals). Different types of shading are employed to represent bioclimatic zones that form the map's basic background (namely hyperarid zones, arid, semi-arid, and subhumid zones).

The short commentary accompanying the Map describes the method that was employed in its preparation. Because of the unavailability of direct data the map was prepared on the basis of indirect assessment of the threat of desertification reflecting bioclimatic data (zones and indices of aridity) and the intensity of human impact (in terms of the densities of human populations and of animal populations). Additional use was made of soil data to subdivide the desertification process into separate categories (deflation, erosion, secondary salinisation).

An Appendix to the commentary contains quantitative characteristics of the desertification processes in individual continents and bioclimatic zones. Let us consider these data (see Table 11).

Table 11

(in thousands of sq km)

Level of desertification hazard	Continents											
	South America		North and Central America		Africa		Asia		Australia		Europe	
	sq km	" " "	sq km	" " "	sq km	" " "	sq km	" " "	sq km	" " "	sq km	" " "
Very high	445	2.4	200	0.8	1,857	6.1	486	1.2	332	4.3	51	0.5
High	1,315	7.3	1,328	5.4	5,032	16.6	5,849	17.3	3,120	10.5	218	2.1
Moderate	1,674	9.3	2,131	12.0	3,839	12.6	5,170	13.1	2,904	37.7	687	6.5
Desert with extremely harsh conditions	207	1.1	54	0.2	6,551	21.6	2,156	6.4				

It may be seen that the largest areas that are already experiencing desertification or presenting desertification hazard are found in Asia (where a high level of desertification prevails), Africa (deserts and territories with high levels of desertification) and Australia. The least areas are typical of Europe (moderate level) and North and Central America. A moderate level also exists in South America. Very high levels of desertification occur in Africa, Asia and South America primarily on territories occupied by developing countries. Hence the very great relevance of desertification problems precisely for such countries.

If one neglects deserts the highest levels of desertification are naturally found in arid zones, while moderate levels occur in semi-arid zones as well as in subhumid zones.

The Conference's third working document was the "Plan of Action to Combat Desertification". It was prepared in draft form before the beginning of the Conference. During the Conference itself it was examined, revised and elaborated. It was adopted in final form at the last plenary session.

The reasons for preparing this plan are briefly described in its first chapter. Generally it restates the definition of desertification processes and the description of their development that were already presented in the Overview. That definition is expressed as follows: "desertification is the diminution or destruction of the biological potential of the land, and can lead ultimately to desert-like conditions".<sup>1</sup>

The Plan's second chapter describes its objectives and principles. Its main objective is viewed as "to sustain and promote, within ecological limits, the productivity of arid, semi-arid, subhumid and other areas vulnerable to desertification in order to improve the quality of life of their inhabitants. It is emphasized that this may be best achieved through optimal forms of land use and through the restoration and protection of natural forces. The plan also gives particular attention to socio-economic problems, since they determine the possibility of adopting concrete decisions in actively opposing desertification and also govern their practical implementation.

The Plan of Action seeks to enhance regional and international opportunities for resolving the problem of

---

<sup>1</sup> The words "desert-like conditions" (presumably natural conditions) are, of course, more accurate than merely "desertification", but they, too, are not as rigorous as "depletion".

desertification, even though it "should be implemented as an efficient, comprehensive, and well-coordinated program of action ... including the establishment of local and national scientific, technical, and administrative opportunities".

Twenty five major recommendations for the Plan are combined in the following groups:

A. evaluation of desertification and improvement in land management;

B. the combination of industrialization and urbanization with the development of agriculture and their effects on the ecology of arid areas;

C. corrective anti-desertification measures;

D. socio-economic aspects;

E. insurance against the risk and the effects of drought;

F. strengthening science and technology at the national level;

G. recommendations for international action and cooperation;

H. recommendations for immediate initial measures.

It is, of course, not possible to relate the contents of all these recommendations. Nor does this seem necessary since the scientific and technological aspects of most of them are generally well known to specialists in arid lands management. This is true, for example, of the recommendations in group C, which generally repeat the findings of the overall survey, and recommendations in group E, as well as some others. Many recommendations in group D and F are very general, even though they do draw attention to extremely important problems. In particular they draw attention to estimates of the role of social, economic, and political factors in desertification processes; to the development of rational economic and demographic policies; to the needs of populations suffering from desertification; to the organizing of a system for monitoring the conditions of human life; strengthening national planning with regard to the rational use of the natural resources; and the assignment of high priorities to national programs to educate and inform individuals concerning problems of desertification.

The recommendations in group G and H emphasize the role of international organizations in implementing the Plan of Action.

The recommendations in group A and B hold a special position. In my opinion they contain a set of fundamental principles that govern approaches to the scientific and

technological as well as socio-economic aspects of the problems being considered.

In group A recommendations relating to estimates of the degree of desertification and improvements in forms of land management refer largely to studies of desertification processes, the planning and organization of economically rational forms of land management, and the effecting of monitoring activities, i.e., of a systematic observation of the state of the environment in arid regions. Even though they do not describe a specific monitoring system they refer to a well organized geographic survey that includes meteorological observations, a water cadaster, a land tenure and land use survey, a census of fodder resources and the development of well-organized pastoral economies. Particular emphasis is placed on the joint need for sectoral and aggregate mapping of natural resources.

Recommendations relating to an effective combining of industrialization and urbanization with the development of agriculture and their influence on the ecology of arid lands (group B) were included following a corresponding proposal by the Soviet delegation. The reasoning underlying that proposal was the following:

The development of industry, mining, cities and transportation facilities is accompanied by a diversity of changes in the ecology of arid zones. There are many examples when industrialization and urbanization have produced or else intensified desertification processes as well as processes of pollution and land degradation. At the same time the experience of many countries has shown that programs for developing arid lands (for creating electrical power stations, new cities and population centres, mining enterprises, and centres of petroleum production as well as of light and heavy industry) can, providing that they are based on reasonable ecological and sociological principles, offer a basis for a full utilization of manpower in supplying cities, industries and agriculture with water, and for a high productivity of labour and a high level of material and cultural well-being.

It can therefore be asserted that the complex approach to the agro-industrial development of lands that is proposed should serve as the principal way for avoiding and overcoming the objective anthropogenic factors leading to desertification processes in arid lands which the Overview describes as unavoidable.

It is evident that these principles largely reflect the Soviet Union's experience in arid lands development. In the USSR's arid regions there are almost no major desertification processes attributable to anthropogenic causes. There are only individual instances of such processes (such as an intensification of wind and water erosion in newly settled regions, local secondary salinization of soils in old oases, and the formation of centres of drifting sands near some of the growing population centres and along new transportation routes), that are being successfully opposed with the help of a variety of technical and agromeliorative measures. Nor can this be otherwise under a planned approach to the economic management of arid regions that relies on scientific principles and purposeful systematic efforts to improve the natural environment.

Detailed and analytically rigorous descriptions of the Soviet experience in developing arid regions were presented in two reports that were prepared for the Conference by Soviet specialists (at the request of its organizers). They were concerned with "Integrated Desert Development and Combat of Desertification in the Turkmen SSR"; and "The Golodnaya (Hungry) Steppe". Conference participants were also able to acquaint themselves with a Soviet study of the Karakum Canal, published in English.

In concluding this description of the Conference it should be stressed that this was the first time that the highly destructive consequences of unplanned forms of developing natural resources on large territories were discussed by a representative international forum. They largely referred not only to influences on the developing countries of Africa, Asia and Latin America from their colonial past but also to influences that are continuing to be felt today. The Conference has shown that the physical causes of such developments are generally known as are the measures needed to avoid and combat them. There were sharp discussions, however, concerning the most effective organization and practical implementation of these measures at the national, regional and international levels. Clearly such measures require large-scale capital investments and the use of modern technology as well as the availability of experienced local specialists and certain socio-economic reforms. The reasons why these questions were not sufficiently resolved at the Conference largely derive from their socio-political character.

The Conference's resolutions are in effect recommendations. And even though their scope is limited, especially with regard to socio-economic aspects, they are unquestionably useful and important in contributing to further international measures and in guiding activities of national organizations.

In concluding I wish to stress that many of the Conference's technical recommendations in fact related to a further strengthening of complex approaches to theoretical and applied scientific research activities. In effect they often concerned a wide reliance on modern constructive-geographic approaches in actively opposing processes of anthropogenic environmental degradation on arid lands. These processes were called "desertification", in the sense that related to anthropogenic disruptions of nature in arid lands under the influence of uncontrolled and poorly organized uses of its natural resources. It would not be appropriate, in my opinion, to use that term in a still wider sense in referring to any substantial disruption of natural conditions and ecosystems in other natural zones (for example, in tundras, forest zones in moderate climates, tropical zones). Attempts to do this violate certain boundaries in defining "desertification", and make that term too general. It seems to me that in addition to that term (the anthropogenic desertification of arid lands) we can employ other terms in referring to other processes. For example, one may speak of natural desertification processes in the very same arid lands that are attributable to uncontrolled natural phenomena (droughts, volcanic eruptions, etc.). At the same time in referring to anthropogenic sources of destruction of natural ecosystems in humid (forest) or other zones (for example in tundras, or highland pastures) it is preferable to use the term "depletion". This will make it possible to identify the essential nature of processes taking place on anthropogenically altered lands more precisely and more fully, and above all to identify correctly the natural potential for self-renewal that particular territories possess as they experience anthropogenic pressure.

## THE PROBLEM OF ECONOMIC AND NON-ECONOMIC ASSESSMENT OF MAN'S IMPACT ON THE ENVIRONMENT<sup>1</sup>

Assessment of man's environmental impact is an important component in the management and optimization of the "man-society-nature" system. The development of methods for arriving at such assessment is especially important for preparing scientific forecasts of approaches to the further development of human civilization. Scientists from various countries and various disciplines have accumulated a significant body of knowledge concerning the mechanisms that govern man's interactions with the environment and have developed a number of corresponding models.

This makes it possible to establish, to some extent, the results of man's impact on the environment and its economic, social and medico-ecological consequences as well as to propose methods for estimating direct economic losses. Estimates of losses attributable to man's environmental impact are quite important in many cases. Above all they must be taken into account in evaluating the economic effectiveness of capital investments on environmental objectives and in planning the development and location of production activities as well as the formation of territorial-industrial complexes.

At the same time it is important to emphasize that the interactions within the "society-environment" system that constitute the scientific basis of both economic and non-economic evaluations have not yet been sufficiently studied.

---

<sup>1</sup> *Geographic Aspects of Interactions within the "Man-Nature" System*, Moscow, 1978 (in Russian).

It would appear that the most important approaches of future studies should be the following:

- further comprehensive studies of interaction and chain reaction mechanisms in natural, economic and social systems and subsystems that are attributable to human activities;
- a search for methods for studying various outcomes or effects, including cumulative ones, arising as a result of various integrating impacts;
- the development of methods for evaluating social, economic and other outcomes.

This last point is especially important since at the present time the damage that is experienced by the environment is established only very partially through various qualitative and quantitative indicators. Above all this is attributable to an insufficiency of quantitative data concerning some impacts and their outcomes as well as concerning relations among them. Secondly, a number of possible harmful consequences that bring about particular forms of damage still cannot be properly valued. This is why studies of the effects of human activities must be interdisciplinary. That will improve the assessment of traditional elements of damage and facilitate the finding of methods of quantitative assessment of consequences that were not considered early.

An intensive research activities in the USSR relate to the development of scientific foundations for the rational utilization of natural resources and for economic evaluations of the positive and negative effects of this type of human activities. Three strategic approaches to such activities have emerged:

1. fundamental theoretical studies of interactions in natural (reference) ecosystems and man-made, i.e. anthropogenic ecosystems;
2. studies of anthropogenic influences on the environment; assessment of both their positive and negative effects;
3. studies of applied problems.

Tactical approaches to such studies are often of the following type:

- studies of structural changes in natural ecosystems and socio-economic systems;
- the finding of stability conditions of natural ecosystems and of their genetic series in relation to various types of anthropogenic influences;
- the finding of stability conditions of socio-economic systems in relation to changes in the environment;

– determined forecasts of the various impacts on individual ecosystem components as well as on entire ecosystem;

– probabilistic forecasts of changes in the environment;  
– probabilistic forecasts of changes in socio-economic systems;

– adjustments of technological and socio-economic development plans in the light of environmental disruptions.

There has been much emphasis on such studies in the USA and other countries, especially in developed capitalist countries. This is attributable to the fact that the United States, for example, leads the world in terms of the intensity of man's environmental impacts. Studies of American researchers, including those of the "Resources for the Future" Corporation, have already led to the development of certain aspects of a methodology for arriving at economic assessment of man's impact on the environment based on a cost analysis and of "benefit-cost" model. Such assessments are based on the magnitude of economic losses attributable to a deterioration of environmental conditions, or else on the direct expenditures that firms are ready to assume (in the form of fines, for example) in order to acquire the right to cause particular forms of damage. In spite of the utilization of statistics and methods of mathematical calculation such estimates are arbitrary, for they are given for a number of variants of a so-called "optimal solution". In practice, most emphasis continues to be given to evaluations of the consequences of air and water pollution, even though American scientists generally agree on the importance of estimates, including non-economic and particularly social comprehensive estimates. It is recognized that the development of the corresponding methodology is an extremely complex matter and studies in that area are at initial stage. It should be stressed that in the USA and other capitalist countries, a fundamental difficulty in solving that problem concerns the nature of the social and economic relations of a market economy. They are marked by antagonistic contradictions among entrepreneurs and other members of society in seeking to arrive at optimal solutions of both local problems of this type and general problems of socio-economic development in the light of sharp deterioration of the environment.

Problems of evaluating the environmental effects of economic activity are receiving much attention in developing

countries as well. There the mutual relation within the "society-nature" system are dynamic in character as a result of the rapid extension of sphere of such interactions, particularly in a territorial sense. They generally constitute a social problem, and not merely a technical and economic one.

The particular importance of geographers and of geographic approaches to interdisciplinary studies concerned with the development of methods for economic and non-economic evaluations of man's impacts on the environment should be stressed. Conducted studies have shown that impacts on nature, and hence corresponding losses as well, and also measures to avoid and overcome them are marked by distinctive geographic differentiation. In recognizing the exceptional importance of this problem and in seeking to combine efforts for arriving at a rapid and effective solution CMEA member countries have initiated joint studies within the framework of the comprehensive research program on methods of economic and non-economic assessment of man's environmental impacts. So-called "model regions" have been established in all countries providing a basis for the elaboration of evaluation methods and also for the probation of the results of international efforts to establish a common methodology for the CMEA countries.

Soviet geographers have chosen the Kursk region as a model one. This is explained by a number of factors, including its location in an economically developed and densely populated zone in which diversified industrial and agricultural production activities take place, and in which one finds both traditional and specific or local sectors in engineering, chemicals, textiles, food industry, agriculture and animal husbandry. All this makes the region representative and typical for conditions of well settled and economically developed parts of the country. Secondly, the fact that the region has long been developed, that its resources are used intensively and that there is a high density of economic activities has produced substantial changes in the region's natural conditions, i.e., deforestation, erosion, and changes in the water balance. Changes brought about by the development of the territorial-industrial complex are further intensified by new large-scale production activities, such as the major iron-ore complex of the Kursk Magnetic Anomaly and nuclear power engineering, which exerts a great influence on the environment.

Today these production activities are developing with due account of environmental and social and health requirements. The latest scientific and technical achievements are employed to avoid radiation pollution in the zones containing nuclear electric power stations. A new city Zheleznogorsk has been constructed for miners at a considerable distance from the iron-ore deposits and of production activities and with due account of wind patterns. This has required very large additional expenditures (to develop a sufficiently effective and reliable protection system and transport workers from their place of residence to work) that may be viewed as costs of avoiding negative effects.

Thus the Kursk region makes it possible to follow changes in the environment, and impacts of both old and new technologies as well as evaluate the role of rational location of socio-economic facilities in reducing negative effects and of determining the proportion of expenditures designed to avoid and compensate damage to the environment.

An important consideration in selecting the Kursk region as a model region was the existence of the Alekhin State Central-Black Earth Reservation, whose natural conditions may be taken as a standard of unchanged nature in studies of anthropogenic modifications of natural complexes. Prolonged studies carried out by the Reservation's staff as well as by scientists of the USSR Academy of Sciences' Institute of Geography have established regularities governing the development of natural complexes in the central forest-steppe region in its original state. In addition energy and material balances (including water balances) have been studied together with their modification in natural and cultivated ecosystems. Important data are provided by research activities of the All-Union Research Institute for the Protection of Soil from Erosion, as well as of the Agricultural, Pedagogical, Medical, and Polytechnical institutes in the city of Kursk; their research concerns individual industries, agriculture, settlements, demographic patterns, and health problems in the Kursk region. Much help is also provided by local organizations and institutions.

## MODERN CONSTRUCTIVE GEOGRAPHIC PROBLEMS OF LARGE CITIES<sup>1</sup>

(written jointly with G. M. Lappo, S. V. Bass, M. Ye. Liakhov,  
V. K. Rakhilin, A. G. Chikishev, L. A. Chubukov) <sup>2</sup>

A continuing increase in the number and size of large cities is a characteristic feature of social development throughout the world. This process, which has been named *urbanization*, is viewed as an unavoidable consequence of general progress in science and technology. As the latter accelerates so does the intensity of urbanization. Enormous industrial "super-cities" develop in industrialized countries, as well as urban agglomerations and conurbations. In developing countries, and particularly in those in which "demographic explosion" is taking place, vast suburban squatter communities develop around former colonial towns.

The progressive urbanization of life in modern societies produces many consequences and is the object of many-sided research. Its consequences are widely known. Aside from the many conveniences of material urban comforts and cultural advancement urban dwellers are also exposed to a variety of undesirable phenomena. These are attributable to such factors as congestion, insufficient amenities in most modern cities, high levels of pollution including increasing noise pollution, etc. Progressive public opinion as well as urban authorities throughout the world have expressed a growing concern with these undesirable consequences of urbanization. Numerous practical measures are being taken to weaken,

---

<sup>1</sup> Published in *Transactions of the USSR Academy of Sciences, Geography Series*, No. 1 (in Russian). Based on a joint contribution to a Conference on Climate, Cities and Man held in Moscow in October 1973.

overcome, or anticipate the various discomforts of urban life. But while their effectiveness varies, on the whole they are entirely inadequate. As a result the negative consequences of urbanization are progressively increasing and produce, or else threaten to produce, a growing deterioration in the life of present and future urban populations.

The basic reasons for the insufficient effectiveness of "anti-urbanistic" measures widely vary. There is no doubt, however, that they include the continually increasing rate of urbanization which is associated with accelerating progress in science and technology and with the increasing intensity of industrial development. Due to a number of social, economic, and other causes "anti-urbanistic" measures are insufficiently effective in counteracting the growing negative consequences of urbanization.

The role of social and economic factors is especially negative under capitalism when any measures designed to protect and improve urban environments that require material expenditures without producing revenue meet with intense and often unsurmountable opposition on the part of owners of urban land, urban buildings, and enterprises. The negative role of these factors is also very substantial in developing countries. This is partly attributable to the limited material resources that are available to them for the protection of urban environments, to a lack of planning, and to their dependence on such supranational factors as the neo-colonial tendency to relocate so-called "dirty" types of industrial production away from the industrial districts of developed capitalist countries.

Socio-economic factors play an altogether different role in this respect in planned socialist economies. The degrees of freedom that are needed to carry out protective and transforming measures derive from the overall humanistic objectives of socialist development, a persistent concern with improving the living conditions of the entire population of the current and future generations, and from social forms of property over the environment and its resources. The effectiveness of such measures is limited primarily by the still inadequate state of corresponding scientific knowledge as well as of methods of economic calculation needed to establish the full consequences of modern urbanization.

. . . . .

## MODERN GEOGRAPHIC STUDIES OF URBANIZATION PROCESSES

The problems of urbanization form the object of multi-disciplinary research. In particular a major role must be played by multi-disciplinary constructive geographic studies.

Modern geographic science studies large cities in terms of the following major aspects:

(a) as regions in which the original state of nature has experienced far-reaching changes, and as areas of intensive anthropogenic intrusion into the normal course of natural processes—in short, as territories possessing particularly difficult environmental problems; this is their *physico-geographic aspect*;

(b) as the highly specific environment of the daily lives of large populations numbering many millions of persons; this is their *biogeographic or ecological-geographic aspect*;

(c) in relation to their role within the territorial structure of economies, their influence on surrounding districts, and their role as intermediaries in interregional interactions; this is their *economico-geographic aspect*.

Naturally all these aspects of comprehensive studies of large cities are closely linked, particularly in constructive geographic studies. Large cities should offer favourable conditions for man's harmonious development. This may be achieved through a goal-oriented regulation of their development. That, in turn, must be based on a knowledge of general principles governing their development as centres of production, science, culture, and administration, and as important links in the entire territorial structure of economies.

All major branches of Soviet geographic science are engaged in precisely such many-sided studies of large cities. These activities have been marked by both important achievements and some substantial lacunae.

In the area of *geomorphology*, for example, which in such a context is closely associated with engineering geology, particular attention is given to the study of different deformations of urban ground, that is to various sinks and sags resulting from intensified suffusion processes, underground fires, anthropogenic karsts, thermokarsts, and the uneven settling of surfaces under buildings.

In many cities the settling of the Earth's surface results

from hydrostatic and hydraulic and dehydration compressions of rock formations, following a prolonged draining of underground waters, a reduction in the coefficient of infiltration of precipitations as a result of the development of waterproof surfaces, the construction of water drainage systems, and the canalization of rivers. A sharp decline in the level of underground waters creates depression sinks in nearly all large cities that are sometimes hundreds of kilometers wide and hundreds of meters deep. Deep settlement troughs that may cover large areas develop over depressions of underground waters.

Changing hydrogeological conditions within city boundaries often induce an intensification of the karst. Anthropogenic karst develops in regions in which salt is mined by using water to dissolve rocks below the Earth's surface.

In large cities located in geocryozones one often finds numerous thermal sag phenomena, frost-induced swellings, and forms of permafrost degradation that significantly alter the local relief. More generally rock compression zones, whose depth may reach 50 metres, are produced by the static and dynamic loads that originate in the weight of large buildings. Settling depressions 0.1 to 0.3 meters deep develop under individual buildings. In cities located in regions of underground mining operations (for example Donetsk, Makeevka, Karaganda) there are displacements of rock formations and an uneven settling of surfaces that may damage buildings and even destroy them. Deformations of the Earth's surface occur over nearly all tunnels and underground subway stations. Displacements of rock formations and surface cave-ins also occur in areas in which there are catacombs and ancient stone quarries.

When considering the growing influence of man's technological and economic activities on urban reliefs serious attention must therefore be given to developing the theoretical foundations of an *anthropogenic geomorphology* of large cities as a specific and highly topical branch of relevant geographic studies.

Both general and specialized studies in the *climatology* of large cities are being carried out. The former include studies of *trends*, that is of unidirectional changes in the major climatic characteristics of large cities. For example, as most large cities grow, gradual increases in the dust pollution due to industrial and household wastes discharged into the

atmosphere are accompanied by growing volumes of toxic substances that frequently exceed maximum concentration limits. The air's oxygen content is reduced while its contents of carbon dioxide increase. Modest temperature inversions are clearly apparent while the ultraviolet part of solar radiation declines.

It has been established that all such trends in climatic characteristics that originate in the large cities themselves may be either amplified or else attenuated by surrounding natural conditions. In particular, the pollution of the atmosphere over a city is amplified when the city is located in large valleys between mountain chains, in zones of wind shadows, and also in regions (and seasons) in which radiation and circulation regimes help produce a stable stratification of the atmosphere.

During the past decade relatively specialized climatological studies of air pollution in large cities have also developed widely in the USSR. One should especially note the activities of the Main Geophysical Observatory in monitoring the concentration of a number of ingredients in many large industrial cities and in developing of methods needed to study theoretical problems. Yet large lacunae continue to exist. In particular, insufficient emphasis is given to studies of the dissemination of urban air pollutants beyond the cities in which they originate under the influence of both general atmospheric circulation and local meteorological conditions.

Studies whose aim is to establish the balance of air pollutants over cities are of theoretical as well as practical importance. They are concerned with identifying polluting substances entering into urban air basins both from the outside and from local sources as well as the quantity of pollutants carried beyond city boundaries and also their dissipation over cities as a result of chemical reactions, precipitation, dissolution, and absorption by plants and of other natural processes. The availability of such balances and of knowledge concerning their genesis will provide a basis for solving the corresponding problems of air pollution more effectively.

Similarly, *hydrological studies* of the territories that are occupied by large cities play an important role and encompass a number of aspects. Studies of the entire water management balance of large cities are needed to provide comprehensive answers to practical requirements. Water management systems produce very substantial trans-

formations in all other elements of the water balance. Empirical findings confirm theoretical expectations that there is an increased precipitation over large cities. This should be expressed in the expenditure items of their water balances. With regard to surface runoff they reflect a transformation of practically the entire surface of a city's territory. Surface runoff increases greatly over areas occupied by various buildings and by waterproof road surfaces. In such places its coefficient approaches one. In the properties of remaining areas which are occupied by parks, gardens, boulevards, lawns and various types of permeable covers differ from those of natural conditions in many respects. Most probably too, there is an increase in the volume of surface runoffs. At the same time there is a sharp decline in the underground runoff. This results partly from the significant decline in contributions from areas with waterresistant or low-waterresistant covers, and partly from the intensive utilization of underground waters by city water management systems. In many large cities this is producing sharp declines in the level of underground waters that limit further increases in their utilization. With regard to evaporation there is general agreement that average air temperatures are higher within city boundaries, and that this develops a potential for increasing rates of evaporation. Besides, a substantial volume of precipitation is intercepted by walls of the buildings that first absorb moisture intensively and then evaporate it completely.

The water balances of urban territories are thus transformed in the following way: precipitation increases, as does surface runoff, underground runoff is reduced, while evaporation, most probably, increases. In addition, a city's water balance exerts a substantial transforming influence on adjoining territories. Since the water requirements of large cities tend to continually increase and local water resources are frequently insufficient, this leads to the development of complex systems for supplying water from outside sources that are occasionally relatively distant. As a result, the water balances of wider territories also change.

The use of water for industrial and household purposes produces large volumes of waste waters, which, after usually passing through some form of treatment, are channelled into collector networks and discharged outside city limits. This naturally produces significant changes in the course of natural material cycle, whose various consequences are, generally unfavourable.

There is wide scope, accordingly, for geographic-hydrological studies of large cities, for currently such studies are generally concerned with individual hydrological problems (such as pollution by industrial and household waste waters). But studies of the entire water resource balance of large cities require knowledge of the precise quantitative, qualitative, and behavioural characteristics of all hydrological elements within a city, as well as of changes by comparison with natural elements. Only when such a scientific basis is available can one expect to arrive at reliable forecasts of changes in both existing and, especially, rapidly developing large urban agglomerations. Such forecasts will permit the development of scientific recommendations designed to fully overcome or else reduce as much as possible the negative influence of cities on the natural water balances of both local territories and wider regions.

*Biogeographic studies* of the role of plants and urban fauna that perform a variety of useful functions in large urban environments hold a special place. Let us recall that one hectare of tree plantings serves the health requirements of at least 30 persons. By creating special micro-climatic conditions urban plants reduce the speed of wind by 30-40 per cent, total radiation by as much as 15-20 per cent, and the direct radiation by 10-12 per cent. In hot weather they reduce air temperature and increase its humidity by as much as 12-15 per cent. In winter, by returning heat, trees increase the surrounding temperature. Urban plants improve the physiological activities of the human organism. Phytocides and zoocides enhance man's ability to work and his resistance to illnesses. Green belts reduce the general level of air pollution by 25-40 per cent and bacteriological pollution by 19-44 per cent. Noise on a street on which trees and bushes are planted is reduced by 14-15 db. It is reduced by 4-8 db in gardens and alleys, and by 19-20 db in large parks. The development of vertical greenery along walls (ivy, wild grapes) protects residential buildings from noise by reflecting 50 per cent of its volume. Finally, plants hold back as much as 80-90 per cent of city dust.

It should be stressed that air pollution in cities operates as a selective factor in relation to plants and encourages the survival of particularly stable species, which may serve as sensitive and reliable bioindicators of particular types of pollution. This calls for the development of a special branch of geographic studies in botany that are closely associated

with urban development. Its task is to clarify the urbanistic "capacities" of various plants: for example wooded plants with sticky and rough leaves serving as natural urban "vacuum cleaners"; of garden plants that operate as absorbers of lead and other harmful pollutants; of broad-leaved tree species (maples, linden) as absorbers of urban noise; and of many plants, for example junipers and bird cherries, as sources of important antibacterial elements.

The pollution of urban soils is especially important for living systems. The soils of industrial regions and cities accumulate large quantities of sulphates, zinc, lead, copper and other substances, and this disrupts the normal nutrition of plants. In addition, it is apparent that as they accumulate in urban soils such technogenic wastes and discharges greatly alter the soil conditions of fauna and flora. This leads to a disruption of soil processes and in particular of their capacity to purify themselves.

Together with many other phenomena this contributes to specific conditions governing the existence of soil fauna in urban settlements. Layers of cement and asphalt practically eliminate all life in urban soils. Soil fauna is forced to concentrate on such "islands of salvation" as lawns and flower beds. It is there that specific animal populations develop that have not yet been studied.

More generally, studies of urban fauna are usually limited to studies of ornithofauna and ichthyofauna and to a lesser extent of individual groups of invertebrates. There are no significant studies of urban terrestrial fauna. At the same time complex processes of assimilation of wild fauna take place in large cities which develop their own biocomplexes. For example, the decline in tree populations reduces the number of nests constructed by many birds (rooks, crows), while the replacement of small wooden dwellings by modern buildings causes fly-catchers, redstarts, wagtails and similar species to disappear. The intensive use of urban green belts by human populations has displaced most species of birds that construct their nests on the Earth's surface. Instead species develop that are typical of parks, such as blackbirds, chaffinches, and linnets. Bird species that are typical of rocky regions, such as bluish-grey pigeons, swifts and martins develop among the tall buildings of large urban environments. At the same time the further extension of suburban irrigated regions produces locations that attract many types of animals in winter that are generally not

characteristic for the given region. But by attracting birds through the development of artificial nesting locations and by establishing cultivated landscapes that meet the needs of particular animals we are able to govern not only the development of animal populations in cities but also their species composition. This is illustrated by the creation of artificial water bodies in which swans, ducks and numerous other esthetic as well as useful representatives of the animal world can live throughout the year.

It is true, of course, that large cities have long been studied systematically from an *economico-geographic point of view*. Much has already been achieved in this respect, particularly in studies of the functional structure of large urban settlements, their types and differentiation, as well as a diversity of problems relating to demography and infrastructures. But in many respects they are still insufficiently comprehensive, complex, and constructive. They are clearly insufficiently linked to physical-geographic studies, which themselves, as we have already noted, suffer from an insufficient emphasis on comprehensive *landscape-oriented* approaches in sectoral studies.

In recent years geographers have initiated studies in *human ecology* that are largely concerned with living conditions in highly urbanized environments. Unfortunately, this work is seriously lagging behind. Research activities are only beginning at a time when answers are already needed to many urgent questions relating to urban development.

The need for substantial changes in the current state of geographic studies of large cities and for a greater precision in the formulation of their problems is made especially pressing by the prospect of a further urbanization of our lives as well as by the constructive rôle of modern geographic science, concerning whose importance we all agree.

#### **THE PROSPECTS OF URBANIZATION: THE FURTHER GROWTH OF CITIES AND THE INCREASINGLY COMPLEX CHARACTER OF URBAN SETTLEMENT**

A consideration of current trends in urban development and their analysis in an abundant literature<sup>1</sup> on urban

---

<sup>1</sup> An example is *Prospects for Urban Development in the Soviet Union*, Moscow, 1973; *Current Problems of Urbanization*, Moscow, 1972; *Geographic Aspects of Urbanization*, Moscow, 1971 (in Russian).

development, geography, economics and sociology make it possible to conclude that the principal features that will characterize impending changes in urban settlements, particularly in the case of large cities, will manifest themselves in the following way.

1. One should expect a further growth in the size of cities (measured in terms of their economic infrastructure, population, territory) attributable to scientific and technical progress. Forecasts relating to urban development in other countries present long-term images of enormous cities whose population numbers tens of millions of persons. Nevertheless, it is clear that given the current "pressure" of man on nature in large cities, current levels of air, water and soil pollution, and clearly excessive physiological loads on urban dwellers such enormous cities, which appear in the context of an unorganized capitalist development, are not viable. They will transform the lives of their inhabitants into a living hell.

There is no doubt that in the planned economies of socialist societies the further growth of large cities will entail a rigorous adherence to specific ecological parameters and will proceed within certain bounds. It may nevertheless be assumed that the tendencies that are currently evident in the development of our large cities (which result from the development of production activities and of the non-material sphere) will continue to be relatively stable until the year 2000. The further growth of cities, including large ones, is one of these tendencies.

2. It is more probable that this tendency will express itself in an accelerated development of *systems of urban settlements*. Thus, an increasingly important role will be played by highly urbanized formations resulting in urban agglomerations, in which positive features will be enhanced as negative features are overcome. In this respect large cities are increasingly effective in playing the role of organizing centres that initiate and stimulate the development of large urban agglomerations.

3. Regions whose geographic location, resources, living conditions, and existing facilities favour agglomeration will tend to merge with each other to form *conurbations displaying a variety of configurations that are elongated in certain directions*. This will mark the beginning of a new stage in urbanization at which it will both attain a higher level and achieve a new quality.

4. An increased emphasis will be placed on the *vertical*

*development of cities* because of the shortage of land and the desirability of compact urban structures. On the one hand, cities will develop vertically and the number of floors in social and industrial and dwelling buildings will increase. At the same time a greater emphasis will be placed on the use of underground space.

5. There will be a continued development and rational organization of *green belts*. In the cities of the future the area occupied by green plants will either equal or exceed the area occupied by buildings. All major cities will be surrounded by suburban zones of forests and parks that will divide satellite cities within urban agglomerations; large avenues and parks within city boundaries will form continuations of these external parks; buildings will be placed on supports in order to create more space for greenery, and considerable emphasis will also be placed on vertical greenery as well as on roof gardens. Specific types of fauna will develop in urban forests and parks.

6. *Suburban zones* will play a major functional role in large cities. Their area will exceed that of the cities themselves by at least ten times. They will provide recreation possibilities for at least 50 per cent of the urban population. Their main function will be to restore health and to serve as zones of mass recreation. But they will serve other functions as well, including the location of branch facilities of central units of industrial enterprises, of research centres and centres of higher education, and of intensive agricultural enterprises supplying cities with fresh products.

7. *General uses of water* will be greatly increased in cities of the future. Aside from fully meeting household and industrial requirements in ways that do not disrupt the local water balance, water basins within the city must serve as a major element in the city's architectural design. The experience of urban development has shown that it is desirable to use rivers passing through large cities as an axis guiding the city's planning design. At the same time internal water bodies (swimming pools, canals) should be greatly extended and employed in many different ways (microclimate, urban fauna, sport activities, etc.).

8. There will be far-reaching changes in the *technology and organization of industrial production activities*. In spite of the declining relative importance of industrial activities as a factor in urban development they will retain their importance as an economic basis in large cities and

agglomerations. Industrial facilities, moreover, will continue to confront large cities with their most difficult problems in the use of land resources, functional zoning, the protection of nature, the state of the environment, patterns of human settlement, and the organization of transportation linkages.

An analysis of current tendencies in the development of urban industrial activities suggests that the use of technological advances and improvements in industrial structure will further increase the safety of industrial activities. Large cities will select sectors and production activities that are relatively safe and will require that harmful industrial activities be located beyond city limits. An increasing role will be played by industrial facilities that do not pollute. Some industries will be relocated underground. In the more distant future one may expect a growing tendency towards a miniaturization of industrial activities that will exert a radical influence on the structure of large cities.

9. The *transportation networks* of large cities will experience fundamental changes. Above all comprehensive constraints (including full prohibition) will be placed on the movement of surface transportation in central districts as well as historic preserves. Priority will be given to public transportation services of various types. Particular emphasis will be placed on the continuous development of both underground and surface transportation facilities. Undoubtedly, the problem of actively opposing air and noise pollution will be resolved in the very near future; together with the utilization of new forms of transportation (e.g. electromobiles) existing transportation systems will be perfected. Corresponding technical possibilities are continually improving.

10. There is no doubt that the *general structure of large cities* will continuously improve. Aside from the development of comfortable urban agglomerations (large cities with satellite cities) the existing structures of large cities that have developed in an unplanned manner will be reconstructed and modernized. Historical centres will be radically reconstructed and will continue to retain their prevailing cultural and partly administrative role. The greater part of cities will consist of residential districts possessing much greenery as well as local trade centres, educational, cultural and administrative institutions. Separating residential areas will be either old or new industrial districts that will be made as comfortable as possible. It is also there, but primarily in

suburban zones, that research "towns" and educational and sports institutions will be established.

If one refers to this very succinct picture of the prospects of further urban development then, in our opinion, the *most important tasks of complex geographic studies* may be described as follows.

The growing size of large cities and the development of urban agglomerations produces an increasing needs for a more rational organization of territories, generate growing pressures on the environment, and extend the scope of its goal-oriented transformation. Large cities and urban agglomerations will require territories possessing a high level of local absorption capacity and a larger volume of resources in support of the city's activities deriving from its nature as a human settlement as well as communal-economic organism. Above all this defines the following principal task for geography: *to identify locations possessing a large natural potential for urban development.*

The vertical development of cities and the active utilization of underground spaces constitute a more intensive penetration into the territory's natural environment. Urban technological systems then enter into a closer interaction with natural systems as many urban buildings of various types are located in environments that permit influences on natural processes that are both intense and specific, and conversely. It is therefore clear that *the spectrum of forecasting geographic-urban studies should be widened.*

The major objectives of complex geographic studies include a *comprehensive analysis of the functional structure of large cities*, of its goal-oriented development in the context of their geographic situation and natural conditions, and of the hierarchical rank of particular cities within existing settlement patterns. They also extend to studies of a basis for selecting its functions together with descriptions of the consequences of further functional shifts.

The encouragement of urban development in zones and regions of very cold or else very hot climates has also produced a need for geographic studies concerned with *special evaluations of zonal conditions*. These require a meticulous identification of those *local conditions* that are relevant to more effective decisions in urban development.

## MAJOR BRANCHES OF CONSTRUCTIVE URBAN GEOGRAPHY

A need has thus emerged for developing a general program of multi-disciplinary geographic studies of the problems of large cities. Within such a program geography's entire methodological arsenal and its characteristic approaches must be applied.

Large cities and large urban agglomerations must be studied by all branches of geography in ways that produce a mutual interaction among them and allocate tasks that accord with the general objective of general integrated research programs. We believe that in such a context a leading role should be played by the study of the environment of large cities and by a corresponding analysis of forms of interaction between nature and society that are particularly complex and particularly dynamic.

Geographic studies of the environments of highly urbanized territories must apply a constructive approach, i.e., develop the geographic foundations of urban development and of regional planning, study geographic principles governing the development of cities and of corresponding systems, and provide geographic reasons and expert estimates for decisions relating to urban development and regional planning. This requires that geographers be able to critically evaluate ideas, conceptions, schemes and projects in urban development from the point of view of geography as a whole as well as of sectoral aspects.

Studies of geographically differentiated factors and conditions governing the development of large cities, of the formation of networks of cities and of the influence of such factors on principles applied to various types of regional zoning (in relation to urban development) would greatly help economic planning, urban development and regional planning. This would form the subject matter of a special branch of geographic science that we will provisionally call *the geography of urban development*. Even though nature's interactions with society are by no means limited to urbanized territories it is there that they develop with particular intensity and are especially dynamic, and it is there that they produce far-reaching consequences for the fate of mankind and the state of its environment. Let us therefore consider this particular aspect of the geography of urban development more closely.

We consider that for methodological purposes it is appropriate to establish the influence of the natural environment:

- on the functional (national economic) basis of cities;
- on the life of urban populations, their labour activities, their modes of living and of resting;
- on urban development;
- on the planning and construction of large cities and urban agglomerations;
- on the functioning (exploitation) of urban economies.

Keeping in mind the wide diversity of natural conditions in the Soviet Union and their clearly differentiated zonal character and keeping in mind as well the progressive movement of cities into the tundra, the northern taiga, deserts, and mountainous regions, geographers should place particular emphasis on studies of the *interaction of nature and cities in extreme natural conditions*. These should not be guided, in our view, by the widely dispersed but usually dominant extraction industries, but should seek to develop relatively large but compact cities through the use of closed planning schemes and the construction of buildings and facilities that conform to the requirements of local conditions. Such cities are better able to withstand harsh environmental conditions and provide a "relatively comfortable environment for the population's vital activities.

But the principal task of modern constructive geography is to rely on a more comprehensive approach in studies of urban development activities *within economically active territories*, in natural zones possessing the most favourable conditions for concentrated urban settlement patterns. An important role in small-scale studies is played by the *development of principles governing different types of regional zoning for purposes of urban development*; the characterization of conditions governing the development of large cities and of urban agglomerations; and the presence, in particular zones, of favourable local combinations of territorial possibilities for large-scale construction activities and recreational resources. In the case of large-scale studies, on the other hand, the principal objective concerns the study of natural landscapes in order to identify their potential possibilities for urban development.

The study of the *geographic situation of large cities* is essential not only in order to gain a knowledge and understanding of existing networks of large urban centres,

but also to forecast their further development. The association of large cities with specific natural zones and subzones, with particular river segments (bends, junctions with major tributaries, points of emergence of rivers from mountains, segments of river deltas) has long been noted in the geographic literature.

At the same time the declining influence of natural factors-- natural resources and conditions--on the location of production activities and of migration patterns has also been frequently noted. Yet one should keep in mind the following considerations.

Modern large-scale industries are increasingly attracted to the use of abundant resources. But these are concentrated in a relatively small number of points. The increasingly wide use of ocean resources is contributing to the development of large joint port and industrial complexes, whose rate of development is particularly rapid. The scale of these activities is very large and they constitute a major characteristic of the shifts that are taking place in the territorial structure of all maritime countries. On the other hand, the need to develop resources located in difficult natural conditions is leading to the establishment of powerful industrial bases that are located outside these regions but whose geographic position is designed to serve them. It can therefore be asserted that rather than merely weakening, the actual influence of natural resources and conditions on the location of industrial activities and on systems of urban population centres is in fact becoming more complex and indirect.

*The influence of large cities on nature* may vary. While small towns do not exert a major influence on natural processes, the "pressure" of large cities on the environment is very substantial. To establish critical thresholds for such an urbanistic pressures is an important research objective that is far from having been met. Relevant information continues to be largely met from a diversity of observations and measurements in ways that generally only make it possible to illustrate individual phenomena and arrive at preliminary and limited conclusions. Corresponding studies should consider processes that derive from the functional structure of cities and also from regional differences.

In estimating urban pressures on nature generally and relating them to city size and to zonal and local environmental characteristics and in extending the scope of such studies it is also necessary to characterize the current

*state of the environment and of environmental changes taking place in various functional parts of large cities.* For example, one may distinguish between central zones, old and new residential districts, old and new industrial districts, mixed production and residential zones, and mass recreation districts. One should also note that the stability of nature's responses to urbanization pressures, its regenerative capacities and rates of regeneration vary greatly in different natural zones. In particular, the extreme vulnerability and slow regeneration of natural systems in the regions of the Far North is widely known.

But aside from acting as a burden on nature large cities also provide protective conditions that facilitate the further development of natural environments. In particular, in regions whose climates are unfavourable the emergence and development of cities produces more favourable environments. Accordingly, such cities represent foreposts of a goal-oriented transformation of nature and of surrounding territories. This is why it is so important to study natural processes on lands that are actively engaged in the performance of urban functions and to forecast the "behaviour" of corresponding natural phenomena.

Constructive geographic studies include the preparation of estimates of the "carrying capacity" of natural environments and the drafting of scientifically grounded recommendations for increasing the local absorption capacity of territories experiencing urbanization. In view of the inevitability of further urbanization and the growth of large cities and urban agglomerations it is extremely important to develop a methodology for forecasting the transformation of natural processes on corresponding territories.

A further development is needed of scientifically grounded constructive *geographic expertise* concerning both concepts of urban development and specific planning decisions at various levels. A clarification is needed of geography's contribution to a critical appraisal of the concept of linear cities, that is of the development of very long urbanized strips (megapololi). Geographic grounds must be developed for establishing specific proportions in large cities and urban agglomerations between open spaces and areas carrying buildings.

Nature must play a major role on future urbanized territories. It should not be simply a recipient of urban pressure and be imprisoned in stone, metal and cement. It must be given assistance in urban environments. It will then

itself facilitate correct solutions to local environmental problems.

Constructive geographic studies of urban development must also be systems-oriented as well as complex. Specific large cities as well as their different functional components should be selected as centres of experimental studies. These should be located in different natural zones and possess different planning structures. A comprehensive range of scientific geographic studies should then be carried out. Aside from sectoral problems (geomorphological, climatological, hydrological, biogeographic, etc.) this also extends to more complex integral physical-geographic and economic-geographic studies. This paper has sought to briefly characterize the substance of such studies. We hope that it will serve as an initial contribution towards further discussions.

# NATIONAL PARKS AS A FORM OF ORGANIZING TERRITORIES FOR REST AND CAMPING<sup>1</sup>

(written jointly with V. S. Preobrazhensky)

The organization of effective rest conditions for workers plays a particularly important role in the USSR where a general increase in the population's level of life is a major task of communist development. It should be recalled that already today, when a five-day working week has been introduced, the number of days of rest each year totals about one-third of the calendar days.

While the material infrastructure of everyday rest activities is provided by cultural organizations located within the population centres themselves (cinemas, theatres, museums, clubs, city parks), the organization of both short-term rest activities (on non-working days) and prolonged (annual leaves) rest facilities is closely linked to the establishment of a "second residence" for each worker and his family as well as to access to favourable natural conditions for active forms of rest on large territories combining forests and fields. A marked increase in corresponding uses of natural wealth in recent years is attributable to several major developments in the field of rest, namely: (1) a five-day working week, which has stimulated short-term rest activities outside population centres; (2) a rapid growth in camping as a leading form of active rest by healthy individuals; (3) a growth in the use of automobiles that is producing a sharp increase in independent trips to forests, rivers, and lakes and to the

---

<sup>1</sup> *Transactions of the USSR Academy of Sciences, Geography Series*, 1979, No. 5 (in Russian).

development of automobile-based forms of camping; (4) the further development of sanatoria and rest homes and their concentration in health and resort zones and the establishment of specialized regimes on corresponding territories.

These tendencies are producing a growing number of campers who are seeking to spend their rest periods away from their city apartments and from centres of population. This is especially visible in the suburban zones of large cities and in the mountain and coastal resort centres. The flow of persons in search of environments conducive to rest and of campers to unsettled territories is growing continuously.

Design organizations and planning bodies, however, continue to view the problems of rest largely in terms of increases in the number of cots and of sleeping accommodations in sanatoria and rest homes. Both the organization and the design of recreational programs continue to be viewed in terms of buildings and complexes of rest homes and sanatoria located in resort areas, of agglomerations of resort centres (such as Greater Sochi, the southern Crimean shore, and the Riga Gulf coast) as well as in terms of tourist camps and boarding houses in such districts. Such a traditional, one-sided "construction-oriented" approach further exacerbates the existing conflict resulting from a disproportion between an exponentially growing flow of persons seeking rest on unsettled territories and the nearly total lack of organizational preparation and scientifically designed as well as legally instituted methods for using such territories and aquatoria outside the areas that are covered by systems of recreational buildings.

It is important to emphasize that the diversity of reliefs of such *unsettled territories*, their forests, meadows, fields, lakes, rivers, natural fauna, pure air, and also their silence may constitute "*basic assets*" of *rest service-providing organizations that are even more important than buildings*. It is therefore no longer possible to solve the ecological, architectural and planning problems of recreation without turning to those that relate to the utilization of the natural complexes of unsettled territories.

A second major point concerns *the use of natural territories for organizing rest conditions for workers viewed as a specific form of economic utilization of land*. For such territories then "work" in the interests of society. That point

is often insufficiently understood. As a result, while there are generally no objections to the assignment of land to the construction of sanatoria, pioneer camps, rest homes, the utilization of land for mass camping activities and for establishing large areas devoted to rest activities often meets with obstacles. This is facilitated by the absence of scientific methods for comparing the economic effectiveness of land use in different sectoral economies, including recreational economies.

The complexity of the situation is further increased by the fact that the administration of the rest services that are currently being developed is scattered among a large number of agencies. As a result that sector is currently unable to withstand the "legal" competition of other economic sectors that have long been established making use of unsettled territories (especially agricultural and forest economies) and possessing operating systems of enterprises. From the legal point of view these are recognized users of land and of forests.

At the same time, just as any other forms of use of natural resources, *rest and camping activities must rely on uses of procedures that are scientifically justified*. Currently there is much concern on the part of natural scientists as well as of the wider scientific community with regard to the need to coordinate uses of territories in regions of mass rest and camping with activities designed to protect nature. The absence of scientifically established procedures and utilization norms for the use of unsettled territories for recreation purposes, as well as of appropriate forms of care and protection for their natural endowments often causes natural complexes to lose the very properties that attract city residents as a source of renewal of their physical and spiritual strength.

Excursions to fields or forests by large numbers of persons (even short visits) inevitably produce specific changes in nature's integrating patterns, and especially in vegetation covers. Even simple anthropogenic loads (not to mention overloads) produce changes in the natural complexes that serve as the basic assets of rest zones. While the character and depth of such changes will naturally differ depending on the character of the natural complexes, the forms of rest, the seasonal patterns and intensity of their use, in the case of the middle zone of the European part of the USSR even simple sport activities, the establishment of tent areas, and the

movement of automobiles in forests without roads quickly lead to the development of wastelands. Disturbances of the topsoil are especially damaging during the humid spring season. In the Urals it was noted that heavy recreational uses of land produced changes in the chemical composition of lake waters. Plans for long-term operations in such zones and districts should therefore consider both slowly accumulating and rapid perturbances, especially of topsoil and vegetation covers. To restore the useful properties of natural complexes periodic interruptions in their exploitation are needed, as well as efforts to facilitate the rapid restoration of such properties to prevent prolonged interruptions in the use of service infrastructures (buildings, roads).

At least two values must therefore be established before rest zones may be safely developed on unsettled territories: their carrying capacity (norms of simultaneous utilization) and the maximum duration of uninterrupted utilization before "operational repairs" as well as "capital repairs" will be needed.

Clearly, in order that particular procedures may be adapted to recreational uses of particular territories the land that is used for rest activities must be assigned to corresponding enterprises on a permanent basis, just as in the case of agricultural enterprises. Accordingly, in addition to stocks of land that have already been created for agricultural and forest enterprises, similar *stocks of land to be assigned for recreational purposes must also be established.*

*National parks* should be one of the major forms of organizing large territories for rest and camping activities especially for prolonged periods of rest. What are the real dimensions, that should be associated with that concept? First, the word "national" is used in the sense of "particularly valuable"; and, secondly, the word "park" is used in the sense of a *territory possessing improved natural endowments.*

Above all national parks must possess *natural conditions that are conducive to effective rest*, i.e., fresh air, a comfortable climate, silence, a diversity of reliefs and types of plants, water bodies, psycho-physiological conditions of rest, and provide a source of esthetic pleasure and *possibilities for dispersion.* It is also desirable that they contain complexes of cultural sites and facilities, and relatively large areas of virgin lands including forests, meadows and water bodies. While their size may be of the order of tens, of hundreds, and occasionally thousands of

square kilometres in the case of forest parks of suburban zones designed to serve short periods of rest, in the case of all-Union zones and regions of prolonged rest, that is of national parks, their areas should cover thousands and tens of thousands of square kilometres.

National parks should possess systems of base camps and automobile grounds for short-term visits by campers, and also residential buildings, stores, repair shops and cultural institutions. Adequate transportation services should link them with densely populated industrial districts where most potential visitors are concentrated.

National parks are not natural reserves. These are *territories employed for recreation and equipped for active forms of rest*. It is precisely their "open" character that defines specific obligations for their administration. Care should be exerted that the carrying capacity of their natural endowments should not be exceeded, and that they preserve and improve those properties that serve their health-restoring functions.

Above all such parks are to be used for rest purposes. This precludes such economic activities as cutting timber, the construction of industrial enterprises, and the extraction of minerals through open pit mining as well as the construction of individual summer homes and the development of communities of summer homes. Enhanced norms should be applied with regard to the preservation of nature. This does not preclude, in our opinion, the possibility of utilizing individual parts of such territories for certain economic purposes (for example, agriculture, hydroelectric power, fish farming in ponds, forest nurseries) providing that they do not seriously disrupt their recreational properties. Most probably, the principle of a comprehensive and many-sided utilization of natural resources providing that specialization in recreation activities retains a dominant role will continue to apply for a relatively long time. It should also be stressed that parks located in forests, and especially in mountain forests, also play an important role in regulating runoff and in preserving the land's water resources.

National parks cannot replace natural reservations, whose function is to preserve areas of so-called virgin nature and its genetic fund for scientific studies. But in cases when they adjoin natural reservations national parks may constitute corresponding "buffer" zones. While the reservations themselves should not be transformed into zones of rest they,

too, may be visited by strictly regulated and controlled excursions in pursuit of educational objectives.

The rational utilization of natural endowments in national parks must be based on a functional regionalization of their land that establishes *several modes of utilization*. Emphasis should be placed on the service facilities mentioned earlier (sleeping facilities, parking areas, cultural institutions, trade and cultural-information centres, cafes and restaurants, etc.), as well as sport facilities and complexes, areas set aside for regulated hunting and fishing activities, and rest areas (zones of silence) in the countryside. There may be additional constraints in zones of silence and of rest in natural environments: a prohibition on the use of motorized means of transportation, loudspeakers, and musical instruments.

Compliance with such modes of utilization is provided by corresponding *territorial planning decisions relating to the technical facilities of territories and modes of care and protection*. Above all park facilities include automobile and bicycle roads, footpaths, and water routes. Also sleeping facilities, including dormitories of tourist centres, rest homes, cabins for fishermen, camping grounds and trailer camps. A rational design of roads and a localization of sleeping facilities and restaurants are not simply a matter of convenience for visitors but also a major means for guiding and dispersing large numbers of persons and a basis for preserving exceptional cultural sites and natural endowments. Cultural and educational facilities play an especially important role. They include information centres, centres of popular education, and museums. Yet effective methods have not yet been found for determining optimal distances between such places of concentration of visitors, on the one hand, and the location of exceptional cultural sites and major natural endowments, on the other. Nevertheless, it is clear that as a rule the location of mass concentration sites near cultural sites and major natural endowments should be avoided.

It is evident that the territories of parks must possess a single manager in a position to coordinate a number of services. The park's administration is such a manager. It must provide for the protection of nature as well as access to it, and must preserve the territory as well as make it convenient for visitors. We are referring to the overall manager of the land and of its natural endowments, and not

only of the buildings, sport facilities, and roads, as is currently the practice.

But the *geographic location of a system of national parks* is also a difficult problem. Since their organization is designed to meet specific needs of society that call, moreover, for capital investments, it follows that unlike networks of natural reservations their spatial configuration systems cannot be simply guided by a knowledge of the location of exceptional cultural sites, major natural endowments, as well as of sights that are simply attractive. *A major factor in designing networks of national parks is a consideration of the corresponding needs for such parks of social groups and age groups of the population in the various regions in which they are concentrated.* Similarly, one cannot neglect the transportation infrastructure. Attempts to solve the problem of park location exclusively on the basis of nature-oriented considerations, or alternatively, of economic considerations will fail.

The problem's complexity leads us to consider the need for *developing a general scheme for a "rest balance" extending to the entire country as well as its major regional subdivisions* (Union republics, territories, and regions) in a way that would *reflect the needs of various population categories of administrative regions for different types of rest and the capacity of territories for rest services.* Balances of this type should be calculated in relation to both current and long-term needs.

The "debit" part of such a balance (needs) relates primarily to social and economico-geographic problems. "Credits" on the other hand, raise specific questions relating to nature itself and in particular concerning the recreational classification of the USSR's natural complexes and their carrying capacities.

*The recreational assessment of the USSR's natural complexes* helps establish the correspondence of current natural and improved landscapes with requirements for various types and forms of rest and camping. It is clear that the same landscape will be of different relevance in various seasons and in relation to various forms of rest (for example, automobile tourism or skiing). Particular complexes should also be assessed for various uses and intensities of use. Quantify assessments must precede the identification of relevant physiological, psychological and esthetic requirements of various types of rest and camping. Geographers

should participate in such studies jointly with doctors, artists and architects.

An important step in establishing the possible capacity of territories of projected parks is the *identification of critical*—maximal admissible—*loads* before there is a disruption of self-regeneration capacities. Such loads should be determined both for the original state of natural complexes and for various levels of their development.

But such assessments form only a step in a comprehensive evaluation of individual territories. In particular, their *economic evaluation* must also be established. Its major components will include estimates of the accessibility of the territory of the projected park in terms of transportation from various population centres, of the possibility of creating local agricultural capacities of the suburban type, and comparative estimates of the cost of technical facilities that will be required. An important role will be played by comparative estimates of the natural complex's effectiveness in other types of economic activity (we have already noted that the assignment of lands to rest and camping facilities will reduce the availability of land and forest resources).

Rest facilities in the USSR are beginning to develop into an independent economic sector, even though their services continue to be administered by dozens of different agencies.

Discussions of the current state and future prospects of natural resources that may serve health, rest, and camping have shown that in spite of existing achievements the development of scientifically grounded rest services has not yet produced a separate branch of knowledge. It constitutes, instead a wide field of activity for many different sciences, including sociology, demography, medicine, economics, urban development, architecture, and all branches of geographic sciences, i.e., sciences concerned with natural, social and technical cycles. We thus face wide-ranging and difficult problems. Efforts to resolve them should be initiated without delay. We, as geographers, are ready to undertake such initiatives. ■







**This book presents a collection of articles by the eminent Soviet scientist Academician I. P. Gerasimov, director of the Institute of Geography of the USSR Academy of Sciences. These articles focus on one of today's most urgent problems—interaction between human society and the surrounding natural world, the rational use of natural resources, and how the modern geographic science approaches this question.**